SURVEY AND INVENTORY OF BULL TROUT POPULATIONS IN THE PLUM CREEK CONSERVATION PROJECT AREA: 1993-1997 METHODOLOGY AND RESULTS

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SURVEY AND INVENTORY OF BULL TROUT POPULATIONS IN THE PLUM CREEK CONSERVATION PROJECT AREA: 1993-1997 METHODOLOGY AND RESULTS

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SURVEY PLAN

TO DETECT THE PRESENCE OF BULL TROUT

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INTRODUCTION

The purpose of this plan is to provide methods for sampling to detect the presence of bull trout *Salvelinus confluentus* on Intermountain Forest Industry Association (IFIA) lands and outside lands of concern. The plan assumes that bull trout are rare (i.e., the probability of collecting an individual in any given sample site is low) and therefore they should approximate the Poisson spatial distribution. Even if the trout are not distributed randomly the Poisson distribution will be adequate if the mean density is very low (i.e., the species is rare), and the spatial distribution is not highly aggregated (Green and Young 1993). The plan focuses on the number of sampling sites needed to detect the presence of at least one bull trout given some target or mean density (i.e., degree of rareness), with some specified probability of detection.

The plan describes procedures for randomly selecting sampling sites for two different scenarios: *watershed approach* and *stream approach*. The sampling approach implemented depends on the area of land owned by the landowner. At each site surveyed several habitat variables will be described. Those variables will be used to assess associations between bull trout presence or absence and habitat features. Finally the plan describes procedures for classifying streams into discrete ecologic, geologic, and geomorphic land-classes. As with habitat variables, associations will be described between these land-classes and the presence or absence of bull trout.

This plan recognizes the potential for bull trout listing to lead to extended interactions with the U.S. Fish and Wildlife Service. For this reason, the plan places high priority on scientific rigor. Scientific rigor, however, increases sampling effort and costs beyond the capabilities of some Association members. Therefore, to meet the needs of all members we made the plan flexible to accommodate different budgets but maintain the highest scientific rigor possible.

We divide the plan into three major parts: *sampling design, data collection*, and *stream ecological classification*. Each section describes in detail the process of collecting data to detect the presence of bull trout.

I. SAMPLING DESIGN

In this section we focus on the number of sites needed to detect the presence of at least one bull trout given some target or mean density (i.e., degree of rareness) and some specified probability of detection. First we describe the sampling distribution that is assumed when sampling to detect a rare species. Following Green and Young (1993), we then derived formulas that estimate the power of the sampling design (i.e., the probability of finding one bull trout in a site) and estimate the number of sites that must be sampled to find bull trout at some given density with some specified probability of detection. Lastly, we describe two different approaches for selecting sampling sites.

I.A. SAMPLING DISTRIBUTION

We believe the sampling distribution should approximate the Poisson, which can be derived from other common distributions (e.g., binomial, negative binomial) by assuming that the event is rare--that the probability of collecting an individual bull trout in any given sample is low. The Poisson model assumes that: (1) each sample site has an equal probability of having an individual bull trout (i.e., bull trout are randomly dispersed among sampling sites), (2) the occurrence of an individual in a site does not influence the presence of another, and (3) the number of bull trout per site is low relative to the maximum possible that could occur in the site (Ludwig and Reynolds 1988).

We recognize that bull trout in some streams are aggregated (distributed in clumps or patches), thus following a negative binomial distribution, not a Poisson distribution. However, even clumped or patchy distributions, such as the negative binomial, approach the Poisson as the event becomes rare and thus the mean density (degree or rareness) becomes small (Green 1979; Green and Young 1993). Furthermore, any formula based on the negative binomial would require an estimate of the parameter k (related to the degree of clumping), and thus would require a mu n greater sampling effort than that needed to simply collect an individual bull trout. The Poisson-based formula, on the other hand, only requires specification of a degree of rareness (mean density) and a probability of detection (power).

I.B. DERIVATION OF SAMPLE SIZE AND POWER FORMULAS

The probability of obtaining X individual bull trout in a single sample from a Poisson distribution with mean density m (degree of rareness) is

$$P_x = m^x(e^{-m}/X!)\,,$$

and the probability of obtaining 0 bull trout (an empty sample) is

$$P_0 = e^{-m}.$$

The probability of obtaining 0 individuals in n independent samples (all n samples are empty) is

$$P_0^n = (e^{-m})^n = e^{-mn}.$$

The probability of obtaining at least one bull trout in at least one of *n* independent samples (the probability of detecting bull trout) is

$$P_{>0,n} = 1 - P_0^n = 1 - e^{-mn}.$$

By rearrangement we obtain

$$n = -log(1 - P_{>0,n})/m \,, \tag{1}$$

which is the number of samples needed to detect the presence of bull trout with power $1 - \beta = P_{>0,n}$. Thus Eq. 1 can be written

$$n = -log\beta/m \,, \tag{2}$$

with power $(1 - \beta)$

$$1 - \beta = 1 - e^{-mn}. \tag{3}$$

For power $1 - \beta = 0.95$, Eq. 2 reduces to the simple relationship

$$n = 3/m \,. \tag{4}$$

Therefore the necessary sample size for a 95% chance of detecting bull trout is equal to 3 divided by the mean density (i.e., degree of rareness) of bull trout.

In a Poisson distribution, the relationship between power and number of sampling sites is nonlinear (Figure 1). That is, at some given density m, the rate of increase in power decreases as numbers of sample sites increase. For example, if the true density of bull trout in a stream is 0.25 fish/100 m, power would increase from 22% to 78% and then to 95% as the number of 100-m long sites sampled increased from 1 to 6 and then to 12, respectively (Table 1). The shape (i.e., rate of change in power with addition of sample sites) of the power curve varies depending on the mean density of bull trout (Figure 1). For example, the increase in power with addition of sample sites is more rapid for a relatively high density population (e.g., 0.4) than for a lower density population (e.g., 0.1).

The Poisson-based formula requires that both the probability of detection (power) and the degree of rareness (mean density) be specified before one calculates the number of sites to be sampled. The first parameter, power, is usually set to some value equal to or greater than $1 - \beta = 0.80$. Power equal to $1 - \beta = 0.80$ has become something of a standard in marine environmental monitoring studies (Green and Young 1993) and in fisheries research (Peterman 1990). A power of $1 - \beta = 0.95$, on the other hand, would balance the conventional $1 - \alpha = 0.95$ confidence level, with Type 1 (probability of finding a bull trout in a non-bull trout stream) and Type 2 (probability of not finding a bull trout in a bull trout stream) error probabilities equal. The objective of the landowner will in part determine power. For example, if a landowner has limited resources and intends to use the presence/absence information internally, not to aid the U.S. Fish and Wildlife Service, then a power of $1 - \beta = 0.80$ is reasonable. However, if the landowner intends to use the data to aid the U.S. Fish and Wildlife Service in their decision process or in legal disputes, then we recommend a power of $1 - \beta = 0.95$. Because sampling efficiency (i.e., error associated with the sampling technique) is compounded with sampling design error, **we recommend that a power of $1 - \beta = 0.95$ be used in the Poisson-based formula.**

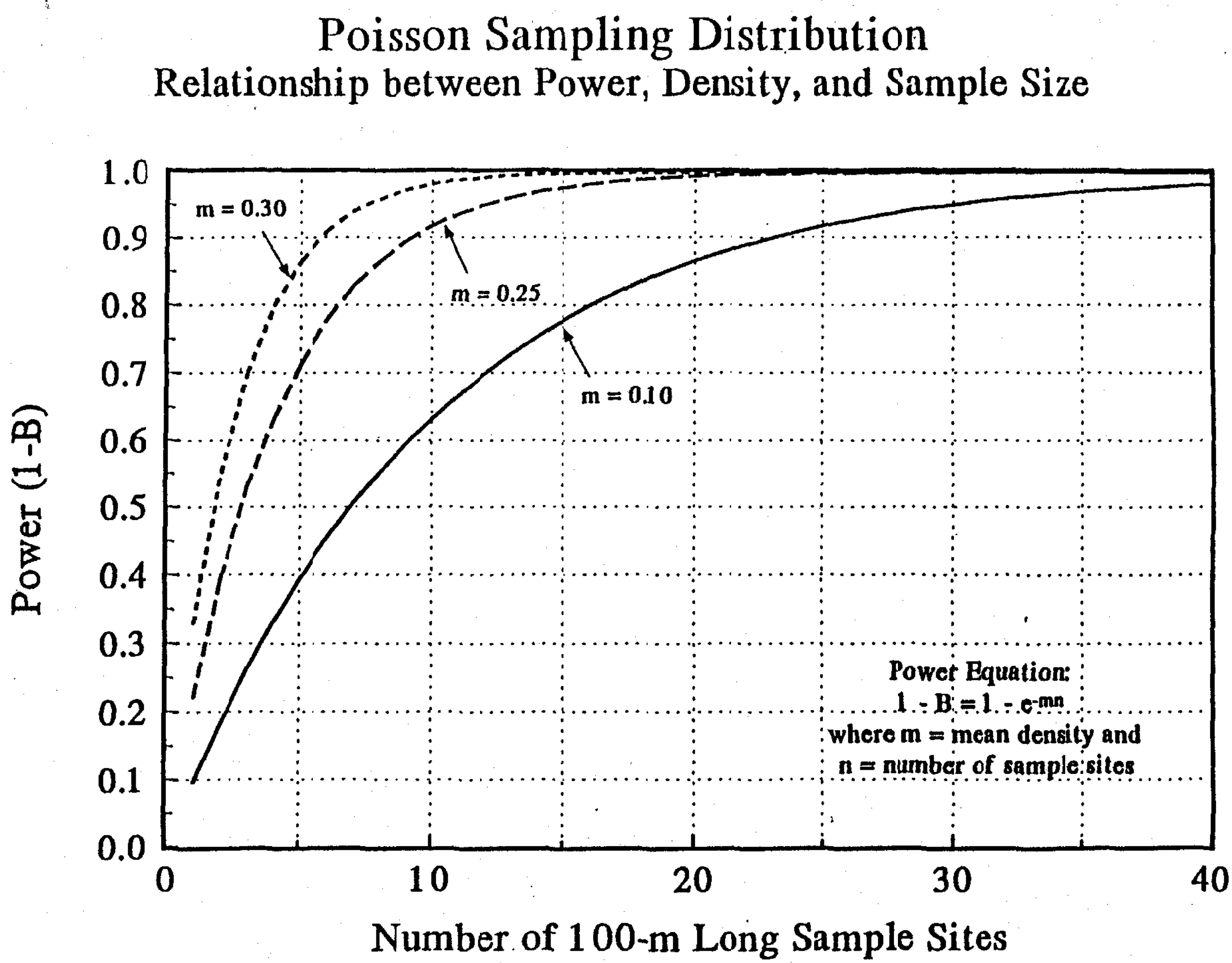


Figure 1.--Relationship among bull trout densities, power (probability of finding one bull trout in a site), and numbers of 100-m long sampling sites for a Poisson sampling distribution. Power curves were generated from data in Table 1.

Table 1.--Probabilities of detecting bull trout in a site (power) given some target or mean density (fish/100 m) and number of 100-m long sample sites.

Number of 100-m long sample sites	Mean density (fish/100 m)						
	0.10	0.25	0.40	0.55	0.70	0.85	1.00
1	0.095	0.221	0.329	0.423	0.503	0.572	0.632
2	0.181	0.393	0.550	0.667	0.753	0.817	0.864
3	0.259	0.527	0.698	0.807	0.877	0.921	0.950
4	0.329	0.632	0.798	0.889	0.939	0.966	0.981
5	0.393	0.713	0.864	0.936	0.969	0.985	0.993
6	0.451	0.776	0.909	0.963	0.985	0.993	0.997
7	0.503	0.826	0.939	0.978	0.992	0.997	0.999
8	0.550	0.864	0.959	0.987	0.996	0.998	0.999
9	0.593	0.894	0.972	0.992	0.998	0.999	0.999
10	0.632	0.917	0.981	0.995	0.999	0.999	0.999
11	0.667	0.936	0.987	0.997	0.999	0.999	0.999
12	0.698	0.950	0.991	0.998	0.999	0.999	0.999
13	0.727	0.961	0.994	0.999	0.999	0.999	0.999
14	0.753	0.969	0.996	0.999	0.999	0.999	0.999
15	0.776	0.976	0.997	0.999	0.999	0.999	1.000
16	0.798	0.981	0.998	0.999	0.999	0.999	1.000
17	0.817	0.985	0.998	0.999	0.999	0.999	1.000
18	0.834	0.988	0.999	0.999	0.999	1.000	1.000
19	0.850	0.991	0.999	0.999	0.999	1.000	1.000
20	0.864	0.993	0.999	0.999	0.999	1.000	1.000

Table 1.--Concluded.

Number of 100-m long sample sites	Mean density (fish/100 m)						
	0.10	0.25	0.40	0.55	0.70	0.85	1.00
21	0.877	0.994	0.999	0.999	1.000	1.000	1.000
22	0.889	0.995	0.999	0.999	1.000	1.000	1.000
23	0.899	0.996	0.999	0.999	1.000	1.000	1.000
24	0.909	0.997	0.999	0.999	1.000	1.000	1.000
25	0.917	0.998	0.999	0.999	1.000	1.000	1.000
26	0.925	0.998	0.999	0.999	1.000	1.000	1.000
27	0.932	0.998	0.999	1.000	1.000	1.000	1.000
28	0.939	0.999	0.999	1.000	1.000	1.000	1.000
29	0.944	0.999	0.999	1.000	1.000	1.000	1.000
30	0.950	0.999	0.999	1.000	1.000	1.000	1.000
31	0.954	0.999	0.999	1.000	1.000	1.000	1.000
32	0.959	0.999	0.999	1.000	1.000	1.000	1.000
33	0.963	0.999	0.999	1.000	1.000	1.000	1.000
34	0.966	0.999	0.999	1.000	1.000	1.000	1.000
35	0.969	0.999	0.999	1.000	1.000	1.000	1.000
36	0.972	0.999	0.999	1.000	1.000	1.000	1.000
37	0.975	0.999	1.000	1.000	1.000	1.000	1.000
38	0.977	0.999	1.000	1.000	1.000	1.000	1.000
39	0.979	0.999	1.000	1.000	1.000	1.000	1.000
40	0.981	0.999	1.000	1.000	1.000	1.000	1.000

According to Kovalak et al. (1986), the second parameter, degree of rareness, must be addressed by the regulatory agency charged with protecting the species. The U.S. Fish and Wildlife Service is coordinating the listing activities for bull trout, but they have not specified a value for degree of rareness. We believe, therefore, that the value should be no greater than the lowest reported density of bull trout in the Pacific northwest. We surveyed the literature and contacted several bull trout ecologists in the northwest to find the lowest reported density of bull trout (greater than 0). Schill (1992) and Larry Brown (personal communication) reported the lowest population densities, 0.25 fish/100 m (2.5 fish/km). **We recommend that 0.25 fish/100-m stream length be used as the density value for degree of rareness in the Poisson-based formula.**

We can now calculate the necessary number of samples needed to detect the presence of bull trout at a density of 0.25 fish/100 m with a 95% probability of detection. Using Table 1, or Eq. 4, it follows that **we must sample 12 sites, each 100-m long, in order to have a 95% chance of detecting bull trout at a density of 0.25 fish/100 m. We would need to sample 7 sites, each 100-m long, in order to have an 80% chance of detecting bull trout at that density.** If we sampled the 12 sites (assuming power of 0.95) and found no bull trout, we would conclude (with a risk of 0.05 of being wrong) that if bull trout occurred in that stream they had a mean density less than 0.25 fish/100 m stream length. This does not mean that there are no bull trout in the stream, just that we are 95% certain that they do not occur at a density of 0.25 fish/100 m or greater.

The density parameter that we used in the Poisson-based formula is dependent on stream length. That is, as stream length increases beyond some given length, densities of bull trout per entire stream length tend to decrease because bull trout typically concentrate in specific areas of long streams or rivers. Therefore, we must identify the maximum length of stream to which the density value of 0.25 fish/100 m would apply. We used the Chiwawa

River, tributary of the Wenatchee River, Washington, to assess the maximum stream length at which we could find 0.25 fish/100 m with power of $1 - \beta = 0.95$. Hillman and Miller (1993) surveyed the lower 52 km of the river for salmonids. They found bull trout throughout the river, but few (18 trout) used the lower 30 km of the river. To find 0.25 fish/100 m with power = 0.95, we would need to divide that segment into 7.2 km reaches. Each reach would then be sampled independently. That is, 12 sites, each 100-m long, would have to be sampled in each reach to find 0.25 fish/100 m. Because it is tedious to divide streams into 7.2 km reaches, we define a sampling reach to be 10 km. **Thus, any stream longer than 10 km would have to be divided into 10-km reaches, and 12 sites, each 100-m long, would have to be sampled within each 10-km reach (including reaches shorter than 10 km).**

I.C. SELECTION OF SAMPLING SITES

Before sampling sites can be selected, landowners must identify streams that may be influenced by operations on their lands. That is, no matter how far the landowner is from the stream, if work on their land can potentially impact the stream, then the stream must be surveyed for bull trout (assuming that no bull trout have been reported in that stream). We recognize that Association members may own an entire watershed, land scattered throughout a watershed, or one or more small parcels of land near a given stream. We therefore designed two sampling strategies: *watershed approach* and *stream approach*. We define a watershed as any land drained by a third-order stream or larger. We follow Strahler's (1952) stream ordering system where a second-order stream is formed by the junction of any two first-order streams; third order by the junction of any two second-order streams. We arbitrarily define a first-order stream as the first blue line that appears on a USGS 7.5 minute series (1:24,000 scale) topographic map. Below we describe the two sampling approaches.

WATERSHED APPROACH--Association members that own watersheds or large portions of watersheds need to survey the network of streams that drain the watersheds for the presence of bull trout. This approach assumes that bull trout can occur in any stream of up to 10-km long in a watershed, except first-order streams, at a density of 0.25 fish/100 m. That means that the number (not density) of bull trout in a stream is related directly to stream length, provided the stream is less than or equal to 10-km long. Therefore, any stream or stream reach of 10 km or less must be sampled with the same intensity (i.e., same number of sample sites regardless of stream length). We exclude first-order streams from the survey because bull trout ecologists generally agree that bull trout rarely use those streams.

The watershed approach begins by identifying the watershed(s) to be surveyed on 7.5 minute series topographic maps, and then ordering the streams according to the Strahler (1952) stream ordering method (e.g., see Figure 2). A watershed can be any drainage larger than a second-order watershed (a second-order watershed is any watershed drained by a second-order stream; third-order watershed is drained by a third-order stream). Within each watershed, identify and exclude all first-order streams from further study. Identify all remaining streams and measure their lengths in kilometers (e.g., see Figure 2). Note that a given stream may start as a second-order stream and end as a fourth-order, or larger, stream. Beginning downstream, divide each stream into 10-km reaches (e.g., see *Figure* 2). Any stream or stream segment less than 10 km will be treated as an independent sampling reach. Divide each sampling reach into 100-m long sites (a 10-km reach will consist of 100 sites; 6.2-km reach will consist of 62 sites). Number consecutively each 100-m site within a sampling reach from downstream to upstream (i.e., site #1 is the downstream-most site; #100 is the upstream-most site in a 10-km reach). From the array of 100-m long sites within each sampling reach, randomly select 12 (power = 0.95) or 7 (power = 0.80) 100-m long sites for survey work (Table 2 provides a list of random numbers). For example, we

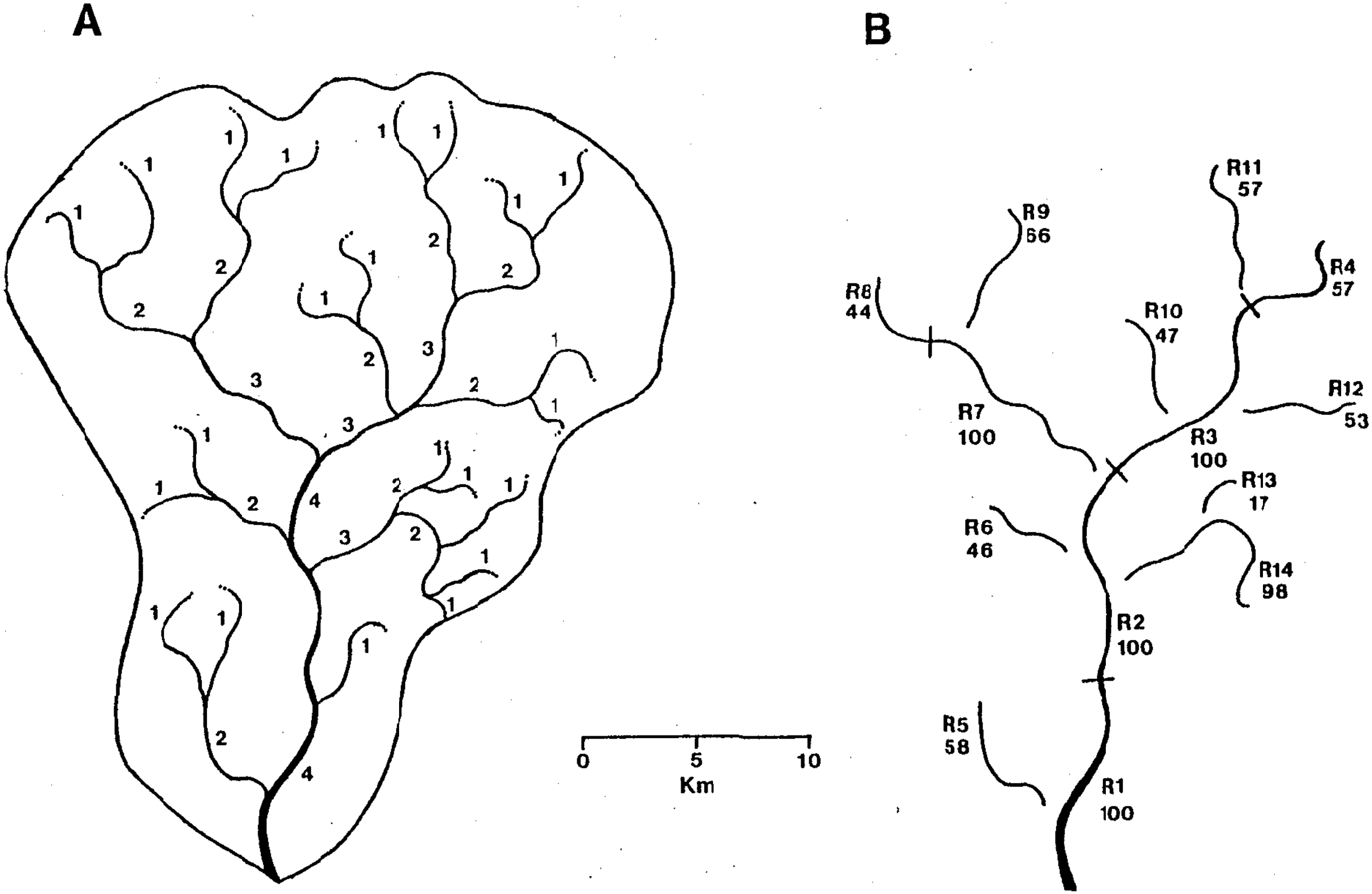


Figure 2.--Example of selecting sampling sites in a fourth-order watershed. Figure A indicates the ordering of streams following Strahler (1952). Figure B shows that all first-order streams are removed and remaining streams are measured for length and divided into 10-km reaches (R). Each reach, or stream ≤10 km, is divided into 100-m long sites (indicated on Fig B as the number under reach; e.g., reach 5 is made up of 58 100-m long sites). For each reach, 12 (power = 0.95) or 7 (power = 0.80) 100-m long sites are randomly selected (e.g., in R1, 12 sites will be randomly selected from the 100 available; R5, 12 sites will be randomly selected from the 58 available).

Table 2.--List of random numbers (in order from smallest to largest) for selecting 100-m long sites in 16 different 10-km reaches. These values can be used only for 10-km long reaches.

Site No.	Independent 10-km Sampling Reaches															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	6	2	3	2	3	2	6	6	2	10	9	3	19	7	9	5
2	16	19	6	9	9	5	12	8	14	12	10	5	25	9	11	11
3	19	22	8	16	10	7	26	21	17	15	13	10	39	19	25	14
4	26	28	29	29	12	13	36	24	20	18	34	11	51	28	26	24
5	30	32	38	35	14	22	39	29	38	19	38	20	55	31	38	25
6	31	41	62	50	20	50	44	31	48	29	45	31	56	34	42	27
7	36	48	69	63	33	58	46	40	52	40	58	34	63	37	51	44
8	46	56	85	68	61	59	52	58	61	42	62	37	64	46	64	60
9	50	63	87	72	73	65	68	69	64	44	76	64	74	50	77	66
10	66	74	94	86	86	72	80	74	76	76	78	65	79	68	87	68
11	77	97	95	90	90	85	88	77	83	79	92	95	96	70	88	73
12	80	100	98	97	98	98	98	91	99	95	95	97	98	74	99	83

use the first column in Table 2 to select sampling sites for Reach #1 (Figure 2B). The first site we would select for fieldwork would be site #6, which is the sixth 100-m long site upstream from the downstream boundary of Reach #1; for the second site we would select site #16, which is the sixteenth 100-m long site from the downstream boundary. We would continue selecting sites for reach #1 until all 12 or 7 sites were identified. For reach #2, we use the randomly selected sites identified in column 2 of Table 2. We would continue this process of randomly selecting sites for each reach until all reaches were surveyed. For streams or sampling reaches less than 1.2 km long, we sample every 100-m long site in that reach (assuming power = 0.95).

We understand that some Association members own several watersheds, or land scattered throughout several watersheds, and cannot possibly survey every stream in each watershed in one summer. We suggest, therefore, that those landowners prioritize streams or watersheds to be surveyed based on their future management plans. High priority streams should be surveyed first, while lower priority streams can be surveyed later. Priority can also be based on streams that have groundwater upwellings. Bull trout tend to prefer stream locations where groundwater upwells (Karen Pratt, personal communication). If landowners first survey in streams with upwellings and find no trout, then they can decide not to survey streams in that watershed that do not have groundwater upwellings. This assumes that if bull trout are not in the preferred stream locations, than it is unlikely that they will be in nearby streams with less preferred habitat. We caution, however, that the 95% or 80% sampling confidence only applies to the streams surveyed, not to the streams that are assumed not to have bull trout. If, however, the landowner finds bull trout in a sampling site, he should stop the survey in that reach or stream (if the stream is less than 10-km long) and begin the survey in the next sampling reach.

STREAM APPROACH.--Association members that own land near a stream (second-order or larger) must survey that stream for bull trout if work on their land can impact the stream. This approach differs from the watershed approach in that only one stream or stream segment is surveyed instead of an entire watershed. Here, the objective is to determine if bull trout reside in the stream adjacent to the land owned by the Association member, and in a 10-km reach downstream from the landowner's property boundary. We include the 10-km reach downstream from the landowner's property because effects on a stream from landuse activities are cumulative downstream. That is, effects are not confined to the stream area immediately adjacent to the landowner's property, but are carried downstream for some distance from that property.

The stream approach begins by identifying on 7.5 minute series topographic maps the stream section (second-order stream or larger) that may be influenced by activities of the landowner. If the section of stream adjacent to the landowner is longer than 10 km, then divide the section into 10-km long reaches measuring upstream from the downstream end of the property line. Add another 10-km long reach immediately downstream from the downstream end of the property line. For example, a landowner must survey three reaches if his property is adjacent to 17 km of stream. Two of the three reaches will be 10-km long: one adjacent to his property and one downstream from his property. The third and upstream-most reach will be 7-km long. Each reach is then divided into 100-m long sites. Within each reach randomly select 12 (power = 0.95) or 7 (power = 0.80) of the 100-m long sites for fieldwork. Thus, the landowner with 17 km of property along a stream would sample 36 sites, each 100-m long, to detect the presence of bull trout with power = 0.95. If the landowner's property is adjacent to 1.2 km of stream or less, then he must sample every 100-m long site within that reach plus 12 randomly selected sites in the 10-km reach immediately downstream from his property. Therefore, with the stream approach, the landowner will always survey at least two reaches. As in the watershed approach, if the landowner finds bull trout in a sampling site then he should stop the survey in that reach and begin the survey in the next reach.

II. DATA COLLECTION

At each randomly selected 100-m long site both fish and habitat variables will be measured (or estimated visually) and recorded on a standard field form (Appendix A). Information from each 100-m long site will be recorded on a separate data form. We divided the data form into three sections: *Site Description, Fish Presence*, and *Habitat Measurements*. Below we describe the variables that are recorded under each section and how those variables are measured.

II.A. SITE DESCRIPTION

Site description provides basic information on the location of a sampling site and a physical description of the sampling site, the stream and its valley. Some of those variables (i.e., valley width, valley bottom type, channel width, state type, channel type, substrate type, gradient, and riparian type) will be tested for associations with the presence and absence of bull trout. Below we describe the Site Description variables.

DATE.--The observer will record the date (month/day/year) the sampling site was surveyed.

COLLECTORS.--Record the names of each team member that participated in the collection of data. We recommend that the survey team be composed of two experienced observers.

STREAM--Record the name of the stream as it appears on Forest Service maps, USGS 7.5 minute series topographic maps, or on official signs. If the stream is unnamed, the recorder should provide a detailed description of the location of the stream in reference to a named stream or drainage.

TRIBUTARY--This refers to the name of the stream that receives the water from the stream you are surveying.

REACH--Record the number of the reach (a reach is 10-km or less) in which you are surveying. This number will correspond to a specific reach identified on a 7.5 minute series topographic map.

SITE.--Record the number of the 100-m long site that you are surveying. This number will correspond to a specific site within a sampling reach that is identified on a 7.5 minute series topographic map.

LOCATION.--The recorder will identify as accurately as possible the location of the sampling site. The description should identify the approximate distance of the site from known landmarks (e.g., roads, bridges, falls, towns, etc.).

VALLEY WIDTH--This measurement is derived from 7.5 minute series topographic maps or in the field. It is measured as the distance (feet) across a valley bottom between the valley bottom boundaries. Boundaries are identified as abrupt increases in the sideslope gradient of adjacent uplands.

VALLEY BOTTOM--Valley bottom types (Appendix B) are distinguished by the geomorphic processes that shape the landscape and are usually distributed in a predictable manner. They correspond with distinctive hydrologic characteristics, especially the relationships between stream and alluvial ground water. With a 7.5 minute series topographic map, the observer can describe the valley bottom type for a survey reach and record a two-digit number corresponding to one of the valley bottom types in Appendix B. For example, if the sampling site is in a reach where the valley bottom is V-shaped with a moderate gradient, then the recorder would report *"31"* as the valley bottom type.

CHANNEL WIDTH.--This is the width (feet) of the bankfull channel. It is measured perpendicular to the stream channel from the top of the left bank to the top of the right bank. Bankfull elevation is identified by scour lines, vegetation limits, changes between bed and bank materials, the presence of flood-deposited silt or abrupt changes in slope.

STREAM STATE.--These describe the present condition of the stream and its banks (Appendix C). Natural streams change state types in response to geo-climatic conditions. An artificially stressed stream can change states through both natural and artificial processes. Using Appendix C, the observer records a numbered code that describes the stream state of the sampling site. For example, the observer would record a *"3"* if the stream banks at the sampling site are laid-back.

ROSGEN CHANNEL TYPE.--Channel type will be identified following the procedures in Rosgen (1993). Rosgen (1993) describes 41 different channel types (Appendix D). There are eight major types that are determined by channel gradient, channel incision and stream sinuosity (channel types A through G). Each of those categories is further divided by dominant substrate types (1 = bedrock to 6 = silt/clay). The recorder will report channel type for each site sampled using the Tables and Figures in Appendix D.

SUBDOMINANT SUBSTRATE.--Rosgen's channel type identifies the dominant channel substrate type. Here the observer records the second dominant substrate using the substrate codes described in Rosgen (1993) (Appendix D). For example, a C-4 type channel indicates that the dominant substrate is gravel. If the second dominant substrate is cobble, the observer would record a "*3*."

GRADIENT.--Channel gradient is the drop in water surface elevation per unit length of channel. Using a clinometer, the observer records the difference in water surface elevation between the upstream and downstream boundaries of the 100-m long site.

TEMPERATURE.--Stream temperature is recorded at each site with a thermometer. Temperature recordings will be used to assess the efficiency of the fish sampling techniques.

TIME.--The field crew will record at each site the time (military time) they began searching for bull trout.

CONDUCTIVITY.--Conductivity (an optional measurement) is a measure of the ability of water to carry a current and depends on the total concentration of ionized substances dissolved in the water. Conductivity is measured with a conductivity meter and expressed in micromhos/cm. Conductivity is used to assess the efficiency of electrofishing.

RIPARIAN: LEFT AND RIGHT.--Riparian habitat is identified as the dominant vegetation along the left and right streambanks (Platts et al. 1987). The rating considers all material (organic and inorganic) on or above the streambank that offers streambank protection from erosion and stream shading, and provides cover or resting security for fish. The area rated is that adjacent to the 100-m long site that covers the exposed stream bottom, bank, and 10 feet beyond the top of the bank. Both sides of the stream channel are rated with numbered codes for vegetation dominance (Appendix E).

II.B. FISH PRESENCE

We suggest that the presence/absence team use two persons. The crew will snorkel first, and if they find no bull trout, they will make a single pass through the site with a backpack electrofisher. Snorkel surveys are advantageous because they do not require collection permits, are relatively inexpensive, and require little equipment. Snorkel surveys should be conducted on clear days during the daytime. Observers can float downstream through a site and search for bull trout if water depth is greater than 3 feet; if water depth is less than 3 feet, observers should crawl upstream through the site. The time spent snorkeling should be about the same in all sites in order to have near equal sampling effort among sites. Presence of one bull trout in the 100-m long site is sufficient to classify the site and reach (10 km survey area) as used by bull trout. The entire 100-m long site should be surveyed for bull trout to estimate roughly their population size (minimum estimate) regardless if a bull trout is found early during the survey in that site.

If the snorkeling crew does not find bull trout, they must then electrofish the site to verify absence. Electrofishing will be conducted by the two-person crew working upstream through the site without block nets. A single pass through the site is sufficient in a presence/absence survey. As with snorkeling, electrofishing effort should be equal among sites. Below we describe the information that is recorded during snorkel and electrofishing surveys.

FISH SPECIES.--Using the fish species codes in Appendix F, the observers record the different species of fish they observed during snorkel and electrofishing surveys. We provide a key to the identification of trout and char in Appendix G.

SIZE.--Observers will record the total length (inches) of the fish they observe or collect. Total length is the distance from the anterior-most part of the fish (usually the snout) to the tip of the longest caudal fin rays. If several fish of the same species are observed, the recorder reports the length of the smallest and largest fish in the sample (e.g., 3 to 14 inches).

RELATIVE ABUNDANCE.--This is recorded as the number of fish estimated during snorkel surveys or counted during electrofishing. Because we do not require the crew to conduct detailed population estimates, we created three categories for reporting abundance: sparse (<10 fish), many (10-50 fish), and numerous (>50 fish).

METHOD.--The observer circles the method (*Snorkel*, *Shock*, or *Both*) used to detect the presence of bull trout. If the crew used both snorkeling and electrofishing to find bull trout, then the recorder circles "*Both*."

II.C. HABITAT MEASUREMENTS

This section requires more information on stream parameters than that given in the site description section. Here we seek specific information on the quantity and quality of stream habitat variables in a sampling site. These data will be tested for associations with the presence and absence of bull trout. Beginning at the downstream end of the site, the observer measures habitat variables for the entire 100-m long site, or 10 consecutive habitat units, which ever is shorter, regardless if bull trout are found in the sampling site. Following Hawkins et al. (1993), we define a habitat unit as an area of the stream with relatively homogeneous depth and flow that is bounded by sharp gradients in both depth and flow (i.e., turbulent fast water, non-turbulent fast water, scour pool, and dammed pool). Below we describe the different habitat variables and how they are measured.

HABITAT TYPE.--This is a specific type of habitat unit. We use Hawkins et al. (1993) Level II classification to describe habitat types (Appendix H). For a habitat type to be classified as a habitat unit, the habitat type must be equal to or longer than the average width of the wetted channel. Using Appendix H, the observer records a numbered code that represents a specific habitat type. For example, if the first habitat unit (downstream-most unit) in the site is a non-turbulent fast water type, the observer records a "2" in the empty cell below the number one. If the next unit upstream is a dammed pool, the observer reports a "4" in the empty cell below the number two. This process would continue until the entire 100-m long site was surveyed, or 10 habitat units were sampled, which ever is shorter.

LENGTH.--This is the length (feet) of each habitat unit described under habitat type. Habitat unit length is measured at the center of the wetted channel from the downstream end of the unit to the upstream end.

WETTED WIDTH.--Wetted channel width (feet) is recorded in each habitat unit identified. The measurement is made across the wetted channel perpendicular to the flow at the point (visually estimated) that represents the average width of the habitat unit.

TAIL CREST DEPTH.--This is measured only in scour pool and dammed pool habitat types. It is measured (feet) at the deepest point where the tail of the channel forming the pool reaches its highest elevation in the downstream direction. The crest can be identified usually as the point where the smooth water surface breaks into a more turbulent surface.

MAXIMUM DEPTH.--This variable is measured in all habitat types. It is measured (feet) at the deepest point (not necessarily the center) in the habitat unit.

SEDIMENT DEPTH.--Like tail crest depth, fine sediment depth (materials <2 mm; e.g., sand, silt, and clay) is measured only in pool habitat types. Sediment depth (inches) is measured at the center of the pool with a 1/4 inch stainless-steel rod with a blunt end. The rod is pushed into the fine sediments until the rod hits substrate larger than sand. If the center of the pool has no fine sediments, then the observer records a sediment depth of "*0*."

PERCENT SURFACE FINES.--The observer visually estimates and records the percentage of the wetted streambed surface area within a habitat unit that is covered with fine sediments (materials <2 mm; e.g., sand, silt, and clay). Percent surface fines are reported for every habitat unit regardless of habitat type.

NUMBERS OF LARGE WOODY DEBRIS (LWD).--This is a count of wood with a diameter greater than 4 inches within the water column. The observer records two numbers. The first number identifies the total number of log jams in the habitat unit. We define a log jam as a cluster of two or more pieces of wood. The second number reported refers to the number of individual pieces of large wood in the habitat unit. For example, if a unit of non-turbulent fast water has three log jams and five individually spaced logs, the observer would record "*3/5*" for the numbers of large woody debris within that habitat unit. If no LWD is found in a habitat unit the observer records "*0/0*."

PERCENT LARGE WOODY DEBRIS COVER.--The observer visually estimates the percent of the wetted surface area of the habitat unit that is covered with large woody debris. Again, large woody debris is any wood within the water column (the wood does not have to be totally submerged in the water) that has a diameter of 4 inches or larger.

PERCENT BOULDER COVER.--The recorder visually estimates the percent of the wetted surface area of the habitat unit that has boulder cover (includes submerged and partially submerged boulders). Platts et al. (1983) define boulders as any substrate with a particle diameter size greater than 12 inches.

PERCENT STREAMBANK UNDERCUT.--The observer visually estimates the percentage of the water surface area in a habitat unit that is covered or influenced by undercut banks. The water surface level does not influence this reading.

PERCENT VEGETATION OVERHANG.--The observer visually estimates the percentage of the water surface area in a habitat unit that is covered with vegetation. Platts et al. (1987) define vegetation overhang as the vegetation overhanging the water column within 12 inches of the water surface. This measure does not include undercut banks.

PERCENT CANOPY COVER.--The observer visually estimates the percent of the water surface area in a habitat unit that is shaded by trees and shrubs that hang over the stream at a distance greater than 12 inches above the stream surface.

III. STREAM ECOLOGICAL CLASSIFICATION

A hierarchical classification will be used to identify reaches of distinctive form, function, and ecological potential. The classification consists of six levels (Table 3). Classes of the top levels consist of large areas that are described based on regional criteria from small scale maps and general information sources. At successively lower levels, these areas are divided into smaller areas that are described based on criteria from large scale maps and on quantitative information. The classification is applied from the top level down, thus accounting for variance at the broadest level possible. Variables of the classification system

Table 3.--Hierarchical levels of classification.

Hierarchical Level	Description
Ecoregion	An area determined by similar land-surface form, potential natural vegetation, land-use and soil (Omernik 1987); it may contain few to many geologic districts.
Geologic District	A portion of an ecoregion with relatively homogeneous *parent materials*, distinguished from surrounding districts by structure, degree of weathering, dominant size-fractions of weathering products and water-handling characteristics; includes both uplands and bottomlands; *it may contain one to* several landtype associations.
Landtype Association	Some part (or all) of a geologic district that is distinguished by a dominant geomorphic mechanism (e.g., glacial, fluvial, alluvial, lacustrine); includes both uplands and bottomlands; it contains several landtypes.
Valley-Bottom Type	*A subset of the valley-bottom landtype distinguished by form, structure and the* manner in which water and sediments move through the system; valley bottom types are generally distributed in a predictable manner along the elevational gradient of watersheds; they contain several to many landforms.
State Type	A part of the valley bottom type distinguished by the condition of the stream and its banks (e.g., eroded bands, laid-back banks, channelized, braided, etc.).
Habitat Type	This is the lowest level of classification and is distinguished as the basic unit of channel morphology (e.g., turbulent fast water, non-turbulent fast water, scour pool, and dammed pool); habitat type develop as mechanisms of self-adjustment to the law of least time rate of energy expenditure (Hawkins et al. 1993).

will be tested for their association with the presence or absence of bull trout. These associations may help us better define a bull trout stream.

ECOREGION.--This is the broadest level of classification (Omernik 1987). It is based on factors (e.g., climate) that cause regional variation in ecosystems or on factors that integrate the causes of regional variations. Principle factors that are used to identify ecoregions are land surface form, potential natural vegetation, land use, and soils. Landowners can determine the ecoregion they are in by using the map in Omernik (1986). The map is available from: Environmental Research Laboratory, U.S. Environmental Protection Agency, Corvallis, OR 97333.

GEOLOGIC DISTRICT.--These are areas of similar rock types or parent materials that are generally associated with distinctive structural features and areas of similar hydrographic character. Structural features are the templates on which streams have etched drainage patterns. The hydrologic character of landscapes is also influenced by the degree to which parent material has been weathered and the water-handling characteristics of the parent rock and its weathering products. Geologic districts do not change to other types in response to land uses, and they include both uplands and bottomlands. Landowners can use USGS Geologic Maps to determine the geologic districts of their lands. Geologic maps can be purchased from: USGS Map Sales, Box 25286, Federal Center, Bldg. 810, Denver, CO 80225.

LANDTYPE ASSOCIATIONS.--These are identified by the dominant geomorphic processes responsible for shaping the landscape and influencing its functional character (Lotspeich and Platts 1982). Glacial, fluvial, alluvial, and lacustrine processes have shaped landscapes and continue to influence the manner in which water and sediments move through ecosystems. Landtype associations are subsets of geologic districts. Landtype associations seldom change in response to cultural practices, include both uplands and the valley-bottom, and are 10s to 100s of square miles in size. Landowners should consult with the U.S. Forest Service to determine landtype associations in their area.

We described Valley Bottom Type, Stream State Type, and Habitat Type in Section IIA. Landowners can use Appendices B, C, and H to determine the respective valley bottom types, state types, and habitat types on their lands.

LITERATURE CITED

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley and Sons, New York, NY.

Green, R. H., and R. C. Young. 1993. Sampling to detect rare species. Ecological Applications 3:351-356.

Hawkins, C. P., and 10 others. 1993. A hierarchical approach to classifying stream habitat features. Fisheries 18:3-12.

Hillman, T. W., and M. D. Miller. 1993. *Estimated abundance and total numbers of* chinook salmon and trout in the Chiwawa River, Washington, 1992. Report to Chelan County Public Utility District, Wenatchee, WA.

Kovalak, W. P. 1986. Sampling effort required to find rare species of freshwater mussels. Pages 34-45 in: B. G. Isom, editor. Rationale for sampling and interpretation of ecological data in the assessment of freshwater ecosystems. ASTM STP 894. American Society for Testing and Materials, Philadelphia, PA.

Lotspeich, F. B., and W. S. Platts. 1982. An integrated land-aquatic classification system. *North American Journal of Fisheries Management 2:138-149.*

Ludwig, J. A., and J. F. Reynolds. 1988. Statistical ecology. John Wiley and Sons, New York, NY.

Markle, D. F. 1992. Evidence of bull trout x brook trout hybrids in Oregon. Pages 58-67 in: P. J. Howe.. and D. V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter of the American Fisheries Society, Corvallis, OR.

McPhail, J. D., and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fisheries Research Board of Canada Bulletin 173:1-381.

Naiman, R. J., D. G. Lonzarich, T. J. Beechie, and S. C. Ralph. 1992. General principles of classification and the assessment of conservation potential in rivers. Pages 93-123 in: P. J. Boon, P. Calow, and G. E. Petts, editors. River conservation and management. John Wiley and Sons, New York, NY.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77:118-125.

Peterman, R. M. 1990. Statistical power analysis can improve fisheries research and management. Canadian Journal of Fisheries and Aquatic Sciences 47:2-15.

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA Forest Service, Intermountain Research Station GTR-INT-138, Ogden, UT.

Platts, W. S., and 12 others. 1987. Methods for evaluating riparian habitats with applications to management. USDA Forest Service, Intermountain Research Station GTR-INT-221, Ogden, UT.

Rosgen, D. 1993. Short Course on stream classification and applications. Wildland Hydrology Consultants, Pagosa Springs, CO.

Schill, D. J. 1992. River and stream investigations: wild trout investigation. Idaho Department of Fish and Game, Sport Fish Restoration, Job Performance Report Project F-73-R-13. 59 p.

Strahler, A. N. 1952. Hypsometric (area-altitude) analysis of erosional topography. Bulletin of the Geological Society of America 63:1117-1142.

Appendix A.--Field data form used to record information on the presence or absence of bull trout and habitat variables in 100-m long sites.

BULL TROUT PRESENCE / ABSENCE FORM

I. SITE DESCRIPTION

Date ______________ Collectors ______________________________

Stream ______________ Tributary ______________ Reach ________ Site ________

Location ____

Valley width ______________ Valley bottom ______________ Channel width ______________

Stream state ______________ Rosgen type ______________ Subdom. Sub. ______________

Gradient ______________ Temperature ______________ Time ______________

Conductivity ______________ Riparian: Left ______________ Right ______________

II. FISH PRESENCE

Fish Species	Size (inches)	Relative Abundance (Sparse <10;Many 10-50; Numerous >50)

Comments:

Method: Snorkel Shock Both

III. HABITAT MEASUREMENTS

Variable	1	2	3	4	5	6	7	8	9	10
Habitat Type										
Length (ft)										
Wetted Width (ft)										
Tail Crest Depth										
Max Depth (ft)										
Sed. Depth (in)										
% Surface Fines										
LWD (jam/indiv)										
Cover: LWD %										
Boulders %										
Undercut %										
Veg Overhang %										
Canopy %										

Appendix B.-- *Valley bottom and sideslope characteristics used to identify valley bottom types (from Naiman et al. 1992).* Channel width is indicated by "X."

Valley bottom type	Valley bottom gradient[a]	Sideslope gradient[b]	Valley bottom width[c]	Channel patterns	Stream order[d]	Landform and geomorphic features
11 Estuarine delta	$\leq$0.5%	<5%	>5X	Unconstrained; highly sinuous; often braided	Any	Occur at mouth of streams on estuarine flats in and just above zone of tidal influence
12 Alluviated lowlands	$\leq$1%	>5%	>5X	Unconstrained; highly sinuous	Any	Wide floodplains typically formed by present or historic large rivers within flat to gently rolling lowland landforms; sloughs, oxbows, and abandoned channels commonly associated with mainstream rivers
13 Wide mainstream valley	$\leq$2%	<5%	>5X	Unconstrained; moderate to high sinuosity; braids common	Any	Wide valley floors bounded by mountain slopes; generally associated with mainstream rivers and the tributary streams flowing through the valley floor; sloughs and abandoned channels common
14 Wide mainstream valley	$\leq$1-3%	$\leq$10%	>3X	Variable; generally unconstrained	1-4	Generally occur where tributary streams enter low gradient valley floors; ancient or active alluvial/colluvial fan deposition overlying floodplains of larger, low-gradient stream segments; stream may actively downcut through deep alluvial fan deposition
15 Gently sloping plateaux and terraces	$\leq$2%	<10%	1-2X	Moderately constrained; low to moderate sinuosity	1-3	Drainage ways shallowly incised into flat to gently sloping landscape; narrow active floodplains; typically associated with small streams in lowlands, cryic uplands or volcanic flanks.

Appendix B.— Continued.

Valley bottom type	Valley bottom gradient[a]	Sideslope gradient[b]	Valley bottom width[c]	Channel patterns	Stream order[d]	Landform and geomorphic features
21 Moderate sloping plateaux and terraces	2-5%	<10-30%	<2X	Constrained; infrequent meanders	1-4	Constrained, narrow floodplains bounded by moderate gradient sideslopes; typically found in lowlands and foothills, but may occur on broken mountain slopes and volcano flanks
22 Alluviated, moderate slope bound	≤2%	<5%, gradually increase to 30%	2-4X	Unconstrained; moderate to high sinuosity	1-4	Active floodplains and alluvial terraces bounded by moderate gradient hillslopes; typically found in lowlands and foothills, but may occur on broken mountain slopes and volcano flanks
31 V-shaped, moderate-gradient bottom	2-6%	30-70%	<2X	Constrained	≥2	Deeply incised drainage ways with steep competent sideslopes; very common in uplifted mountainous topography; less commonly associated with marine or glacial outwash terraces in lowlands and foothills
32 V-shaped, high-gradient bottom	6-11%	30-70%	<2X	Constrained	≥2	Same as above, but valley bottom longitudinal profile steep with pronounced stair-step characteristics
33 V-shaped, bedrock canyon	3-11%	70% +	<2X	Highly constrained	≥2	Canyon-like stream corridors with frequent bedrock outcrops; frequently stair-stepped profile; generally associated with folded, faulted or volcanic landforms

Appendix B.– Continued.

Valley bottom type	Valley bottom gradient[a]	Sideslope gradient[b]	Valley bottom width[c]	Channel patterns	Stream order[d]	Landform and geomorphic features
34 Alluviated mountain valley	1-4%	Channel adjacent slopes <10%; increase to 30% +	2-4X	Unconstrained; high sinuosity with braids and side-channels common	25	Deeply incised drainage ways with relatively wide floodplains; distinguished as "alluvial flats" in otherwise steeply dissected mountainous terrain
41 U-shaped trough	<3%	<5%; gradually increases to 30% +	>4X	Unconstrained; moderate to high sinuosity; side channels and braids common	1-4	Drainage ways in mid to upper watersheds with history of glaciation, resulting in U-shaped profile; valley bottom typically composed of glacial drift deposits overlain with more recent alluvial material adjacent to channel
42 Incised U-shaped valley, moderate-gradient bottom	2-5%	Steep channel adjacent slopes, decreases to <30%, then increases to >30%	<2X	Moderately constrained by unconsolidated material; infrequent short flats with braids and meanders	2-5	Channel downcuts through deep valley bottom glacial till, colluvium, or coarse glacio-fluvial deposits; cross-sectional profile variable, but generally weakly U-shaped with active channel vertically incised into valley fill deposits; immediate sideslopes composed of unconsolidated and often unsorted coarse-grained deposits
43 Incised U-shaped valley, high-gradient bottom	6-11%	Steep channel adjacent slopes, decreases to <30%, then increases to >30%	<2X	Moderately constrained by unconsolidated material; infrequent short flats with braids and meanders	2-5	Channel downcuts through deep valley bottom glacial till, colluvium, or coarse glacio-fluvial deposits; cross-sectional profile variable, but generally weakly U-shaped with active channel vertically incised into valley fill deposits; immediate sideslopes composed of unconsolidated and often unsorted coarse-grained deposits

Appendix B.-- Concluded.

Valley bottom type	Valley bottom gradient[a]	Sideslope gradient[b]	Valley bottom width[c]	Channel patterns	Stream order[d]	Landform and geomorphic features
44 Active glacial outwash valley	1-7%	Initially <5%, increasing to >60%	<4X	Unconstrained; highly sinuous and braided	1-3	Stream corridors directly below active alpine glaciers; channel braiding and shifting common; active channel nearly as wide as valley bottom
51 Moderate-gradient valley wall/ headwater	3-6%	>30%	<2X	Constrained	1-2	Small drainage ways with channels slightly to moderately entrenched into mountain toe-slopes or headwater basins
52 High-gradient valley wall/ headwater	6-11%	>30%	<2X	Constrained; stair-stepped	1-2	Small drainage ways with channels moderately entrenched into high gradient mountain slopes or headwater basins; bedrock exposures and outcrops common; localized alluvial/colluvial terrace deposition
53 Very high-gradient valley wall/ headwater	11% +	>60%	<2X	Constrained; stair-stepped	1-2	Small drainage ways with channels moderately entrenched into high gradient mountain slopes or headwater basins; bedrock exposures and outcrops common; localized alluvial/colluvial terrace deposition

[a]Valley bottom gradient is measured in length of *ca.* 300 m (1000 ft) or more
[b]Sideslope gradient characterizes the hillslopes within 1000 horizontal and *ca.* 100 m (300 ft) vertical distance from the active channel
[c]Valley bottom width is a ratio of the valley bottom width to active channel width
[d]Stream order as defined by Strahler (1952)

Appendix C.--Description and codes of stream state types. State types are identified from aerial and/or ground reconnaissance and 1:6,000 or 1:8,000 scale aerial photographs.

Code	State type	Description of state type
1	Natural	Banks in straight reaches are stable and overhanging; point bars are vegetated; cut banks are vegetated, stable, and usually overhanging.
2	Eroded banks	Banks in straight reaches are mostly eroded and unstable; point bars are mostly vegetated; cut banks are eroded and nearly vertical; bankfull width is less than twice baseflow width at bends.
3	Laid-back banks	Banks in straight reaches are eroded; point-bars are mostly nonvegetated; point bars may be cut off during high flows; cut banks are eroded or laid-back; bank-full width is greater than twice base-flow width at bends.
4	Channelized	Stream sinuosity has been diminished to protect roads, railroads, urban development, industrial facilities, and other man-made features.
5	Cut-off point bars	Laid-back point bars have been cut-off forming backwaters and islands at base flow.
6	Mine tailings	Mine tailings are the dominant substrate and bank-forming material; most tailings are not vegetated.
7	Braided	Braided channels result from deposition of sediments (channel aggradation).
8	Impounded	Tailwaters of reservoirs.
9	Multiple channel	Multiple channels result from erosion of substrates.
10	Straight	Similar to channelized but not confined by man-made features; natural features restrict lateral movement of the channel.
11	Entrenched	Channel has cut the base of high terraces or residual slopes on at least one bank; high banks are unstable and constitute sediment sources to the stream.

Appendix D.--Classification of channel types. Tables and Figures from Rosgen (1993).

Table 2. Summary of delineative criteria for broad-level classification.

Stream Type	General Description	Entrenchment Ratio	W/D Ratio	Sinuosity	Slope	Landform/Soils/Features
Aa+	Very steep, deeply entreached ,debris transport streams.	<1.4	<12	1.0 to 1.1	>.10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with/deep scour pools; waterfalls.
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	<1.4	<12	1.0 to 1.2	.04 to .10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in assodated step-pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	>12	>1.2	.02 to .039	Moderate relief, colluvial deposition and/or residual soils. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate w/occasional pools.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad,well defined floodplains	>2.2	>12	<1.4	<.02	Broad valleys w/terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channel. Riffle-pool bed morphology.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	n/a	>40	n/a	<.04	Broad valleys with alluvial and colluvial fans. Glacial debris and depositional features. Active lateral adjustment, w/abundance of sediment supply.
DA	Anastomosing (multiple channels) narrow and deep with expansive well vegetated floodplain and associated wetlands. Very gentle relief with highly variable sinuosities. stable streambanks.	>4.0	<40	variable	<.005	Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition w/well-vegetated bars that are laterally stable with broad wetland floodplains.
E	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	>2.2	<12	>1.5	<.02	Broad valley/meadows. Alluvial materials with floodplain. Highly sinuous with stable, well vegetated banks. Riffle-pool morphology with very low width/depth ratio.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4	<12	>1.4	<.02	Entrenched in highly weathered material. Gentle gradients, with a high W/D ratio. Meandering, laterally unstable with high bank-erosion rates. Riffle-pool morphology.
G	Entrenched "gulley" step/pool and low width/depth ratio on moderate gradients.	<1.4	<12	>1.2	.02 to .039	Gulley, step-pool morphology w/moderate slopes and low W/D ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials; i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.

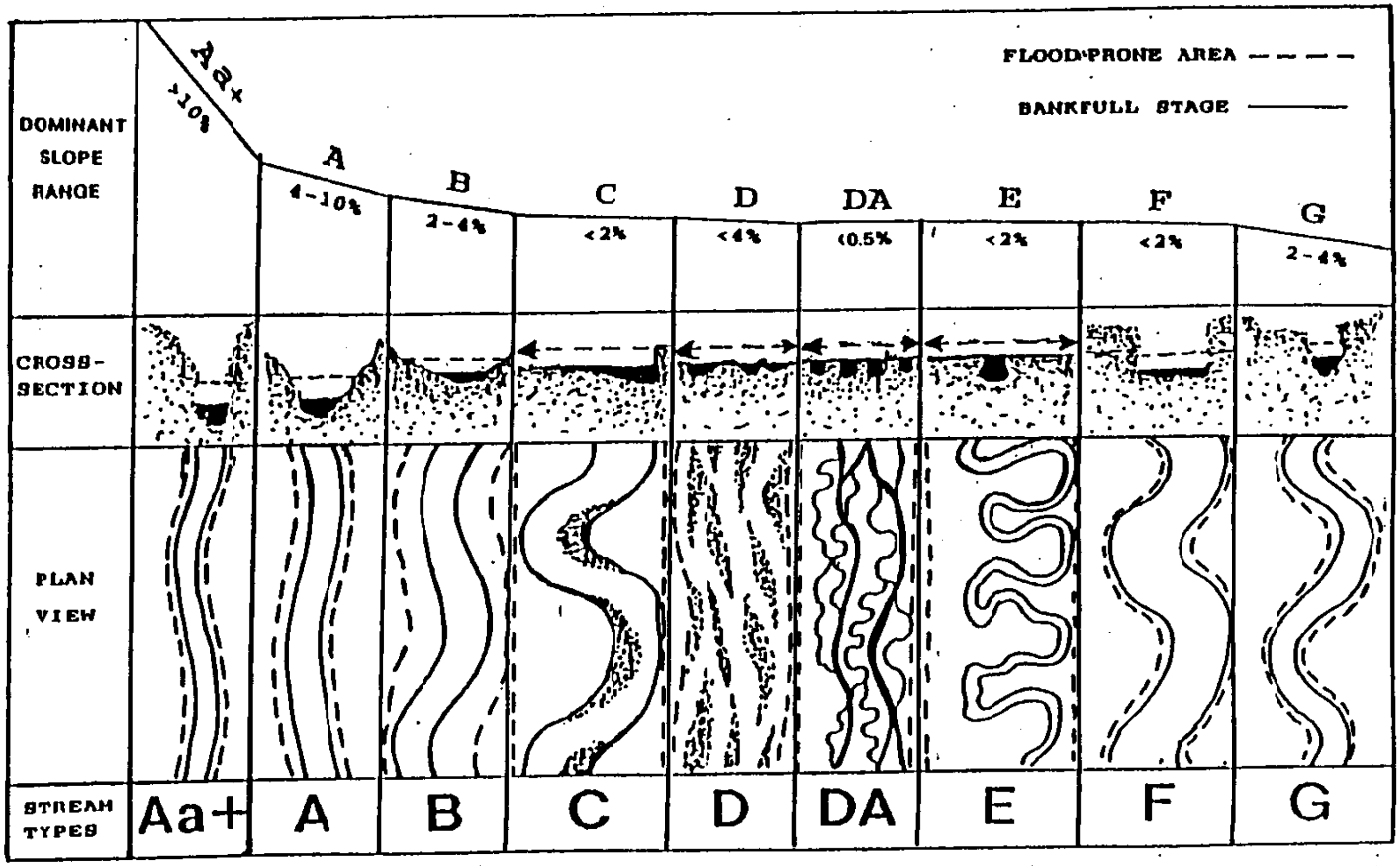
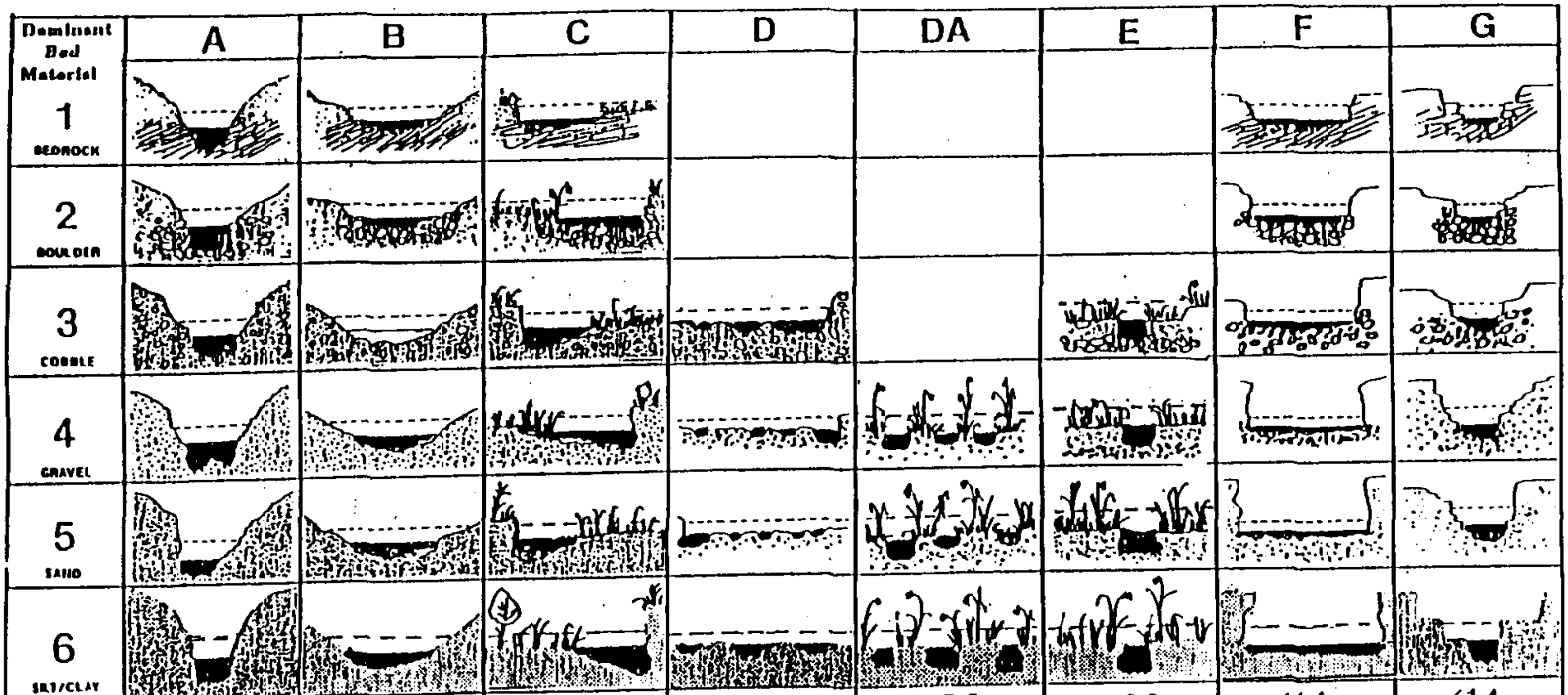
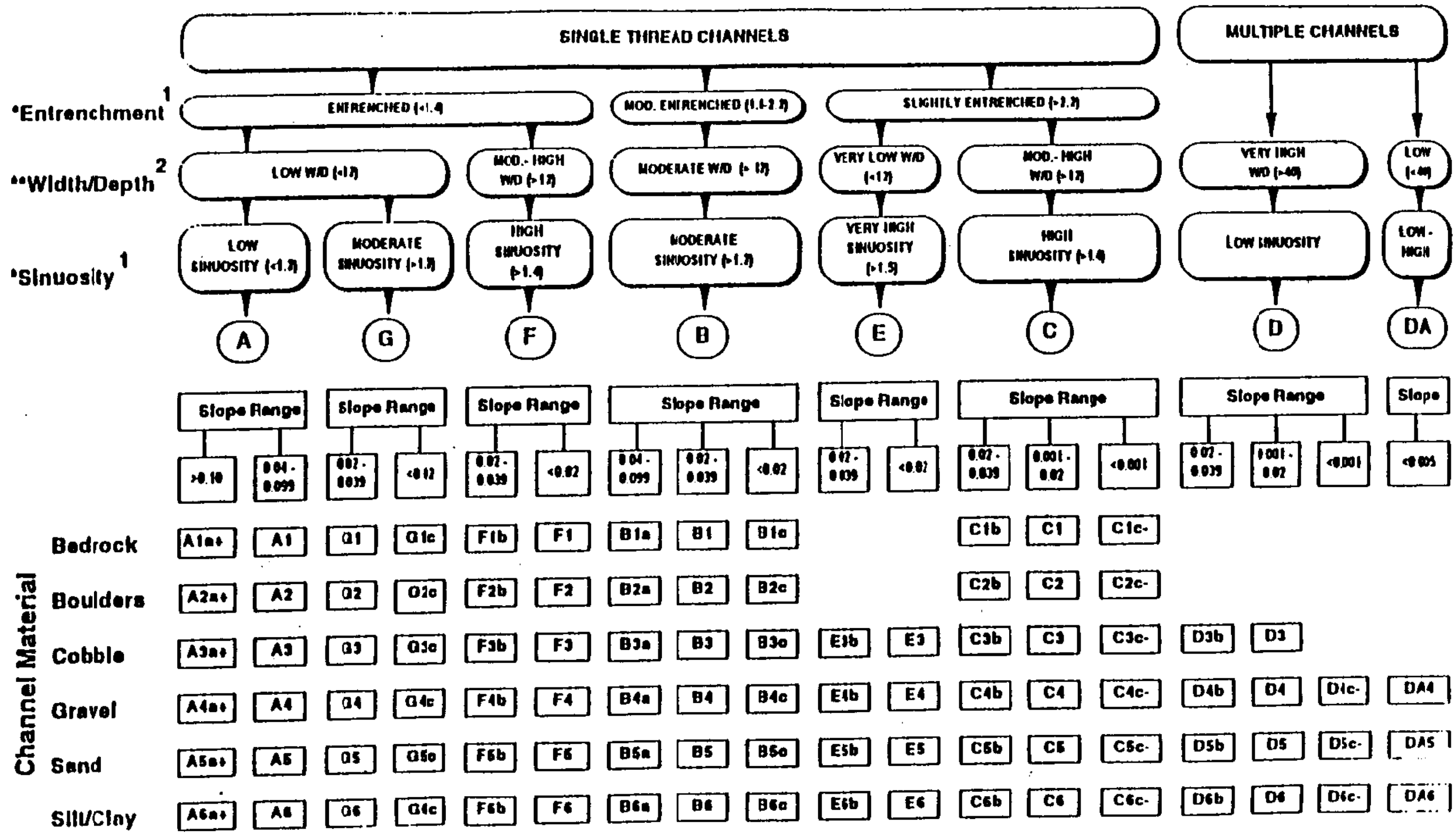


Figure 1. Longitudinal, cross-sectional and plan views of major stream types.



	A	B	C	D	DA	E	F	G
ENTRH.	<1.4	1.4-2.2	>2.2	N/A	>2.2	>2.2	<1.4	<1.4
SIN.	<1.2	>1.2	>1.4	<1.1	1.1-1.6	>1.5	>1.4	>1.2
W/D	<12	>12	>12	>40	<40	<12	>12	<12
SLOPE	.04-.099	.02-.039	<.02	<.02	<.005	<.02	<.02	.02-.039

Figure 4. Illustrative guide showing cross-sectional configuration, composition and delineative criteria of major stream types.



1 Values can vary by ± 0.2 units as a function of the continuum of physical variables within stream reaches.
2 Values can vary by ± 2.0 units as a function of the continuum of physical variables within stream reaches.

Figure 5. Key to classification of natural rivers.

Appendix E.–Riparian rating codes used to describe streamside vegetation.

Rating	Description
5	Shrubs are the dominant streamside vegetation.
4	Tree forms are the dominant streamside vegetation.
3	Grass forms are the dominant streamside vegetation.
2	Forbs are the dominant streamside vegetation.
1	Over 50% of the streambank has no vegetation and the dominant bank material is made up of such materials as soil, rock, bridge materials, road materials, culverts, and mine tailings.

Appendix F.–Fish Species Codes.

Code	Description
BL	Bull Trout *Salvelinus confluentus*
BK	Brook Trout *Salvelinus fontinalis*
BBH	Bull/Brook Hybrid *Salvelinus* sp.
RB	Rainbow Trout *Oncorhynchus mykiss*
CT	Cutthroat Trout *Oncorhynchus clarki*
BN	Brown Trout *Salmo trutta*
WF	Whitefish *Prosopium* sp.
SC	Sculpin *Cottus* sp.
SU	Sucker *Catostomus* sp.
DA	Dace *Rhinichthys* sp.
SH	Shiner *Richardsonius* sp.

Appendix G.--Key to the Identification of Some Juvenile Trout and Char (McPhail and Lindsey 1970)

A. Dark spots on light-colored background, spots on dorsal fin small and numerous; width of dark areas along lateral line less than width of light areas.

1. Cutthroat trout *Oncorhynchus clarki*

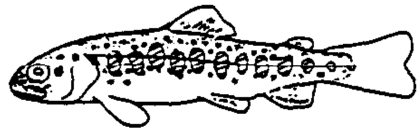
Caudal fin with spots; five or fewer dark median parr marks (often none) ahead of dorsal fin; usually some black spots on caudal fin, particularly at the base; red to yellow hyoid marks in the two parallel grooves under the chin, may be absent in very small fish, black border of adipose fin usually with one or more breaks; hind margin of maxilla may reach to or past hind margin of the eye (not in very small fish).

2. Rainbow trout *Oncorhynchus mykiss*

Caudal fin without spots; 5-10 dark median parr marks along mid-dorsal line ahead of dorsal fin; few or no spots on tail; no red or yellow hyoid marks (in the two parallel grooves under the chin); black border of adipose fin with one or no breaks; hind margin of maxilla not reaching hind margin of eye.

3. Brown Trout *Salmo trutta*

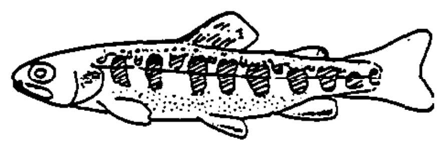
Small black spots above and below the lateral line in addition to the parr marks; about 11 parr marks, none as wide as the eye diameter; larger fish may have distinct red spots.



B. Spots on dorsal fin large and few or forming vague blotches; colored spots (red or yellow) on lateral line between or on parr marks (may be missing in hatchery-reared fish); combined width of dark areas along lateral line about equal to or greater than width of light areas.

1. Brook Char *Salvelinus fontinalis*

No definite dark spots other than parr marks below the lateral line; 8 or 9 large, pear-shaped and sometimes irregularly spaced parr marks, the widest about equal to the eye diameter; fish may have pronounced vermiculation (worm-like markings) on the dorsal surface; lower fins with white or white/black/red stripes on leading edge.



2. Bull Char *Salvelinus confluentus*

Parr marks smaller than those on brook char, circular or oval blotches often blending with the colors along the back, and usually poorly defined; more pronounced light colored spots above the lateral line with less distinctive spotting on dorsal fin than on brook char.

3. Bull x Brook Hybrids (Markle 1992)

Identification of a bull x brook hybrid in the field is difficult based on visual characteristics. Colors and body markings tend to be intermediate between brook and bull char. Hybrids have a spotted dorsal fin pattern; brook trout have a banded dorsal fin pattern and bull trout have a solid dorsal fin pattern. The presence of both adult forms may be a good indication that hybrids are also present.

Appendix G2.--Cutthroat trout have dark spots on the sides; caudal fin covered with rows of black spots on sides (no red spots or orange spots on sides); red or orange slashes between bones of lower jaw

Appendix G3.--Rainbow trout have dark spots on the sides; caudal fin covered with rows of black spots (no red or orange spots on sides); no red or orange slashes between bones of lower jaw. Illustrated by Ron Pittard.

Appendix G4.--Brown trout have dark spots on the sides; caudal fin without rows of black spots; red or orange spots often present on sides.

Appendix G5.--Brook char have light spots on the sides; discrete black spots and wavy blotches (vermiculation) on the dorsal fin; distinct black bar behind white edges on pelvic and anal fins.

Appendix G6.--Bull char have lights spots on the sides; no discrete black spots or blotches on dorsal fin or black bars on pelvic and anal fins, only dusky areas present.

Appendix H.--Codes and descriptions of the four habitat types in the Level II classification of Hawkins et al. (1993).

Rating	Description	Examples
1	Turbulent Fast Water	Falls, Cascades, Rapids, Riffles, and Chutes.
2	Non-Turbulent Fast Water	Sheets and Runs
3	Scour Pool	Eddies, Trenches, Mid-channel pools, Lateral pools, and Plunge pools.
4	Dammed Pool	Debris, Beaver, Landslide, Backwater, and Abandoned channel.

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Friends of the Bull Trout Conference Proceedings. 421 - 425.

Implementation of a Method to Detect the Presence of Bull Trout

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Abstract - The potential for listing the bull trout, *Salvelinus confluentus* as a threatened or endangered species in the United States necessitates the development of a survey method to detect the presence or absence of bull trout in any given drainage. We implemented a statistically based survey method that, with some specified probability of detection, delineates the intensity of sampling needed to detect the presence of at least one bull trout given some assumed population density. From June through October 1993, 43 streams (about 490 km) in Idaho, Montana, and Washington were surveyed for the presence of bull trout, assuming a minimum population density of 2.5 fish/km. Snorkeling and electrofishing were used to detect, identify, and enumerate bull trout and other species of fish encountered. Various habitat measurements were reported to assess any correlations with fish presence and abundance. Six of the streams surveyed contained bull trout. The six bull trout streams identified had varied land management histories ranging from essentially undisturbed watersheds to watersheds with many decades of human disturbance. The same range of human disturbances was also noted in watersheds where no bull trout were detected. These findings suggest that the degree of disturbance within a watershed may not be a reliable parameter for predicting the presence or absence of bull trout in any given watershed. Additionally, survey methods used previously may not have been rigorous enough to detect bull trout at low population densities.

Because the bull trout, *Salvelinus confluentus,* has the potential to be listed under the Endangered Species Act, land managers and fisheries biologists will likely have extended interactions with the U.S. Fish and Wildlife Service concerning this species. Such interactions will necessitate the acquisition of information regarding the distribution of bull trout populations within and across various land ownerships, both public and private. A review of the existing literature indicated that no survey methodologies had been developed that were rigorous enough to meet the expected needs of land managers or the U.S. Fish and Wildlife Service. For this reason, a methodology was developed to detect the presence of bull trout in any given third to fourth order watershed (Hillman and Platts 1993). In order for this sampling methodology to meet the needs of land managers and state and federal agencies, it must be rigorous enough to detect bull trout at low population densities with a high degree of confidence.

This method was also designed to sample selected landform, drainage pattern, and aquatic habitat parameters on an hierarchical basis. This approach was selected in order to gain more knowledge of habitat assemblages associated with bull trout populations. Acquisition of this knowledge has been designated as a priority by researchers (Rieman and McIntyre 1993; Platts et al. 1993). An hierarchical approach is preferred because past studies have noted relationships between salmonid populations and basin geology (Fraley and Graham 1981; Nelson et al. 1992) as well as aquatic physical habitat features (Buckman et al. 1992; Goetz 1989; Weaver and Fraley 1991). Therefore, a methodology that allows for the integration of landform and fluvial processes may provide for discrimination of bull trout habitat preferences within varied geologic types.

In addition to incorporating the measurement of abiotic habitat components into this methodology, relative densities of other salmonid species, native and introduced, are needed to evaluate the potential for competition with, or displacement of, bull trout. Several authors (Ziller 1992; Dambacher et al. 1992; Buckman et al. 1992; Clancy 1993) have noted the likelihood of competitive displacement and/or hybridization between bull trout and introduced salmonids. Hence, this factor must also be considered as a potential determinant regarding the presence or absence of bull trout in a watershed.

Methods

The methods we used to detect the presence of bull trout in a stream were, in part, developed by Hillman and Platts (1993). Below we describe briefly the methodology.

Sampling Design

It was first necessary to determine the intensity of sampling within a given length of stream to detect at least one bull trout. In order to do so, it was necessary to ascertain: 1) the expected minimum population density of the target species; 2) the sampling distribution; and 3) the probability of detection (sampling power).

The expected minimum population density was determined by a literature review and discussions with bull trout researchers with extensive sampling experience. The lowest reported density for a population of bull trout was 0.25 fish/100 m (Schill 1992; L. G. Brown, Washington Department of Wildlife, personal communication; T. M. Weaver, Montana Fish Wildlife and Parks, personal communication). Therefore, the assumed minimum population density was set at 2.5 fish/km.

The distribution of bull trout in streams should approximate the Poisson, which can be derived from other common distributions (binomial, negative binomial) by assuming that the event is rare, (i.e., the probability of collecting an individual bull trout in any given sample is low). Even though bull trout in some streams may be aggregated, thus following a negative binomial distribution, these distributions approach the Poisson as the event becomes rare (Green 1979; Green and Young 1993).

In order for the survey technique to have a high probability of detection, the desired sampling power was set at 95%. Even though a sampling power of 80% has become something of a standard in fisheries research (Peterman 1990), a more rigorous sampling power of 95% would be better suited to fit the needs of land managers and the U.S. Fish and Wildlife Service (Hillman and Platts 1993).

We assumed that 100 m sampling transects would be adequate to capture habitat variation within streams that were fourth order or less. By derivation of the Poisson-based formula and through computer simulation, it was determined that for any 10 kilometer reach of stream, twelve 100 m long, randomly located transects would need to be sampled to meet the desired sampling power of 95% (Figure 1).

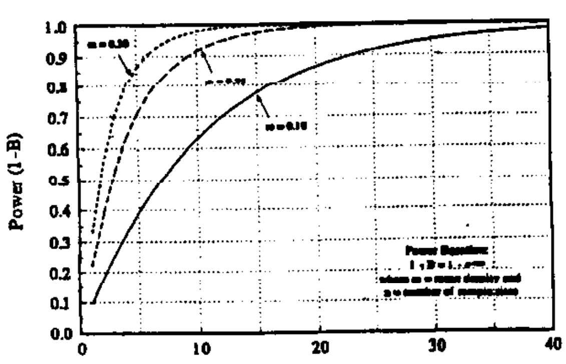


Figure 1. Relationship among bull trout densities, power (probability of finding one bull trout in a site), and numbers of 100m long sampling sites for a Poisson sampling distribution.

Site Selection

Since juvenile fluvial and adfluvial and resident bull trout often live only in smaller watersheds (Rieman and McIntyre 1993), second- to fourth-order watersheds were selected for sampling. Watersheds selected were those where insufficient or no information existed concerning the presence or absence of bull trout. All of the sampled watersheds were within the historic range of bull trout and were not upstream of any apparent passage barriers. An additional criterion was that we wished to sample watersheds where land management activities were expected to occur in the near future (1 to 3 years). Forty-three watersheds in the states of Montana, Idaho, and Washington were selected for sampling during the June through September 1993 field season. These watersheds were within the following major drainages: upper Clark Fork River, Kootenai River, Flathead River, Priest Lake, St. Joe River, upper Clearwater River, Yakima River, Green River, and Pend Oreille River.

Once a watershed was selected, 7.5 minute USGS quads were used to classify the streams according to the Strahler (1952) stream ordering method. All first-order streams were identified and excluded from further study. All remaining streams were identified and lengths were measured in kilometers. Beginning at the downstream end of the watershed, each stream was divided into ten km sampling reaches. Any stream or stream segment less than ten km was treated as an independent sampling reach. Twelve 100 m sampling sites were then identified and located for each ten km sampling reach by use of a random numbers table. Once all sampling sites were located, data were collected at each randomly selected site. Sampling proceeded from the downstream-most site upstream. For all watersheds, crews examined enough 10 km sampling reaches to effectively sample at least 60% of the cumulative stream length of second- through fourth-order streams within the entire watershed.

Data Collection

Four categories of data were collected at each sample site: Site Description, Fish Presence, Habitat Measurements, and Stream Ecological Classification.

Site description provided basic information on the location and physical description of the sampling site, the stream and its valley. Parameters recorded include: sample reach number, site number, site location, valley width, valley bottom type, bankfull channel width, stream state, Rosgen channel type, subdominant substrate, gradient, temperature, and riparian vegetation type.

Fish species, size class, and relative abundance were observed and recorded using snorkel surveys and single-pass electrofishing through the 100 m site. Fish species were grouped into size classes using 75 mm intervals, and for each species and size class observed, a relative abundance code was recorded. Relative abundance codes were: sparse(<10 fish), many(10-50 fish), and numerous(>50 fish).

Habitat measurements required specific information on the quality and quantity of stream habitat variables in a sampling

Table 1. Survey results for 1993.

State	Drainage	Tributary to	Reaches sampled	Species Captured[*]
Montana	Lazy	White Fish Lake	1	EB
Montana	East Fisher	Silver Butte	1	WCT, EB
Montana	Owl/Himes	East Fisher	1	WCT
Montana	Shaffer	Pipe	1	WCT, RB
Montana	*Schroeder*	*Thompson*	*1*	*EB, WCT, BT*
Montana	Payton	Flathead Lake	1	EB
Montana	Tamarack	Little Bitterroot	1	RB
Montana	Beaver	Swan	1	WCT, EB, RB, BN
Montana	Bear	Blackfoot	1	EB, WCT, YCT, RB, BN
Montana	Fincly	Placid Lake	1	WCT, EB
Montana	Fawn	Clearwater	1	WCT
Montana	East Twin	Blackfoot	1	WCT, RBEB, RB, BN
Montana	W. Fork Petty	Clark Fork	1	WCT, EB
Idaho	Pack	Brushy Fork	1	WCT
Idaho	U. Brushy Fork	Brushy Fork	1	WCT
Idaho	N. Fork Spruce	Brushy Fork	1	WCT
Idaho	Twin	Lochsa	1	WCT
Idaho	Walton	Lochsa	1	BT
Idaho	Parachute	Papoose	1	WCT
Idaho	Red Raven	Saint Joe	1	WCT
Idaho	Alpine	Saint Joe	1	WCT
Idaho	Lick	Saint Joe	1	WCT
Idaho	Sisters	Saint Joe	2	WCT
Idaho	Fishhook	Saint Joe	2	WCT
Idaho	Boulder	Mica	1	WCT
Idaho	Spotted lewis	Little N. Fork Clearwater	1	WCT
Idaho	Lost Lake	Little N. Fork Clearwater	1	BT
Idaho	Montana	Little N. Fork Clearwater	1	BT
Idaho	Caribou	Priest Lake	1	WCT
Washington	Sema	Granite	1	WCT
Washington	LeClerc	Pend Oreille	1	WCT
Washington	W. Branch LeClerc	Pend Oreille	2	BT
Washington	E. Branch LeClerc	Pend Oreille	2	BT
Washington	M. Branch LeClerc	Pend Oreille	1	CT
Washington	W. Fork Teanaway	Yakima	1	RB, CT
Washington	Big	Yakima	2	CT, RB, EB
Washington	S. Fork Taneum	Yakima	1	CT, RB, EB
Washington	*N. fork Taneum*	*Yakima*	*2*	*CT, RB, EB*
Washington	French Cabin	Cle Elum Lake	1	EB, RB
Washington	Green	Green	1	CT, EB, RB, COHO
Washington	Twin Champ	Green	1	RB, CT
Washington	N. F. Little Naches	Naches	1	RB, CT
Washington	M. F. Little Naches	Naches	1	RB, CT

[*]Key: EB = Eastern Brook Trout, WCT = Westslope Cutthroat Trout, CT = Cutthroat Trout, YCT = Yellowstone Cutthroat Trout, RB = Rainbow Trout, BN = Brown Trout, BT = Bull Trout, COHO = Coho Salmon

site. Beginning at the downstream end of the site, habitat variables were measured for the entire 100-m long site, or ten consecutive habitat units, whichever was shorter. According to Hawkins et al. (1993) Level II classification, a habitat unit is defined as an area of the stream with relatively homogenous depth and flow that is bounded by sharp gradients in both depth and flow (i.e., turbulent fast water, non-turbulent fast water, scour pool, and dammed pool). To be recorded, a habitat unit must be equal to or longer than the average width of the wetted channel. For each habitat unit the following habitat variables were measured: length; wetted width; tail crest depth (for pools); maximum depth; percent surface fines; number of large woody debris (individual pieces and jams); percent large woody debris cover; percent boulder cover; percent streambank undercut; percent vegetation overhang; and percent canopy cover.

An hierarchical classification was used to identify reaches of distinctive form, function, and ecological potential. The classification consisted of three levels. Variables of the classification system will be tested for their association with the presence or absence of bull trout. Levels of classification, by decreasing level, were: valley bottom type, stream state type, and habitat type.

Results

Of the 43 watersheds surveyed in 1993, six contained bull trout (Table 1). The six bull trout streams identified had varied land management histories ranging from essentially undisturbed watersheds to watersheds with many decades of human disturbance. The same range of disturbances was also noted in watersheds where no bull trout were detected. Bull trout observed ranged from the 0-75 mm size class to the 225-300 mm size class.

Three of the six streams in which bull trout were detected (Walton, West Branch LeClerc, East Branch LeClerc) had previously been surveyed by the U.S. Forest Service with no detection of bull trout. Review of their survey techniques indicated that their sampling intensity was not as rigorous as the one described here. At this time, not enough data are available from our surveys to allow for a statistically reliable comparison between bull trout streams and non-bull trout streams to assess habitat preferences.

Discussion

Because we found bull trout in watersheds with diverse histories of management, our findings suggest that the degree of disturbance within a watershed may not be a reliable parameter for predicting the presence or absence of bull trout in any given watershed. Additionally, since bull trout were detected in watersheds that had previously been surveyed without detection, we assume that survey methodologies used previously were not rigorous enough to detect bull trout at low population densities. This may in some instances provide a compelling reason for biologists to resurvey some watersheds with greater rigor.

In 1994, we plan to continue using this method to improve and expand bull trout distribution information in Washington, Idaho, and Montana. We also plan to compare the effectiveness of night snorkel surveys versus day snorkel surveys and day electrofishing in streams with low densities of bull trout. This test has been suggested by some researchers who found higher densities during night snorkeling than during day snorkeling (Goetz 1991).

Lastly, we will use this methodology in streams known to support both low and high population densities of bull trout. Here, our intent is to increase the sample size of habitat data from streams occupied by bull trout. We will then use multivariate analyses to assess if some combination of the hierarchical array of habitat parameters can be used to predict the presence of bull trout in any given watershed with some degree of statistical confidence.

References

Buckman, R. C., W. E. Hosford, and P. A. Dupee. 1992. Malheur River bull trout investigations. Pages 45-57 *in* Howell, P. J. and D. V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop, Oregon Chapter of the American Fisheries Society, Corvallis.

Clancy, C. G. 1993. Aquatic environment and fisheries 1993 monitoring report. Bitterroot drainage including Bitterroot National Forest. Montana Department of Fish, Wildlife and Parks, Hamilton, Montana.

Dambacher, J. M., M. W. Buktenica, and G. L. Larson. 1992. Distribution, abundance, and habitat utilization of bull trout and brook trout in Sun Creek, Crater Lake National Park, Oregon. Pages 30-44 *in* Howell, P. J. and D. V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop, Oregon Chapter of the American Fisheries Society, Corvallis.

Fraley, J. J., and P. J. Graham. 1981. Physical habitat, geologic bedrock types and trout densities in tributaries of the Flathead River drainage, Montana. Pages 178-185 *in* N. B. Armantrout, editor. Acquisition and utilization of aquatic inventory information: Proceedings of the symposium; October 28-30; American Fisheries Society, Western Division, Portland, Oregon.

Goetz, F. 1989. Biology of the bull trout, *Salvelinus confluentus*, a literature review. U.S. Department of Agriculture, Forest Service, Willamette National Forest, Eugene, Oregon.

Goetz, F. 1991. Bull trout life history and habitat study. U.S. Department of Agriculture, Forest Service, Deschutes National Forest, Final Report, Contract 43-04GG-9-1371, Oregon.

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley and Sons, New York, New York.

Green, R. H., and R. C. Young. 1993. Sampling to detect rare species. Ecological Applications 3:351-356.

Hawkins. C. P., and 10 others. 1993. A hierarchical approach to classifying stream habitat features. Fisheries 18:3-12.

Hillman. T. W.. and W. S. Platts. 1993. Survey plan to detect the presence of bull trout. Don Chapman Consultants. Boise. ID. Prepared for Intermountain Forest Industry Association. Coeur d'Alene, Idaho.

Nelson. R. L., W. S. Platts. D. P. Larsen. and S. E. Jensen. 1992. Trout distribution and habitat in relation to geology and geomorphology in the North Fork Humboldt River drainage. northwestern Nevada. Transactions of the American Fisheries Society 121:405-426.

Peterman. R. M. 1990. Statistical power analysis can improve fisheries research and management. Canadian Journal of Fisheries and Aquatic Sciences 47:2-15.

Platts. W. S., M. Hill. T. W. Hillman. and M. D. Miller. 1993. Preliminary status report on bull trout in California. Idaho. Montana. Nevada. Oregon. and Washington. Don Chapman Consultants. Boise, ID. Prepared for Intermountain Forest Industry Association. Coeur d'Alene, Idaho.

Rieman. B. E., and J. D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. General Technical Report. INT-302. U.S. Department of Agriculture. Forest Service. Intermountain Research Station. Boise. Idaho

Schill. D. J. 1992. River and stream investigations: wild trout investigation. Sport Fish Restoration. Job Performance Report Project F-73-R-13. Idaho Department of Fish and Game. Boise.

Strahler. A. N. 1952. Hypsometric (area-altitude) analysis of erosional topography. Bulletin of the Geological Society of America 63:1117-1142.

Weaver. T. M.. and J. J. Fraley. 1991. Fisheries habitat and fish populations. Flathead basin forest practices. and fisheries cooperative program. Flathead Basin Commission. Kalispell. Montana.

Ziller. J. S. 1992. Distribution and relative abundance of bull trout in the Sprague River subbasin. Oregon. Pages 18-29 *in* Howell. P. J. and D. V. Buchanan. editors. Proceedings of the Gearhart Mountain bull-trout workshop. Oregon Chapter of the American Fisheries Society. Corvallis.

PLUM CREEK BULL TROUT SURVEYS
1993, 1994, 1995 and 1997 RESULTS FOR MONTANA, IDAHO & WASHINGTON

KEY FOR 1993-1997 SURVEYS:

EB = Eastern Brook Trout, CT = Cutthroat Trout, BT = Bull Trout

RB = Rainbow Trout, BN = Brown Trout, WF = Whitefish

COHO = Coho Salmon, KSA = Kokanee Salmon, SH = Shiners

CSA = Chinook Salmon, DA = Dace, SC = Sculpin, SU = Sucker

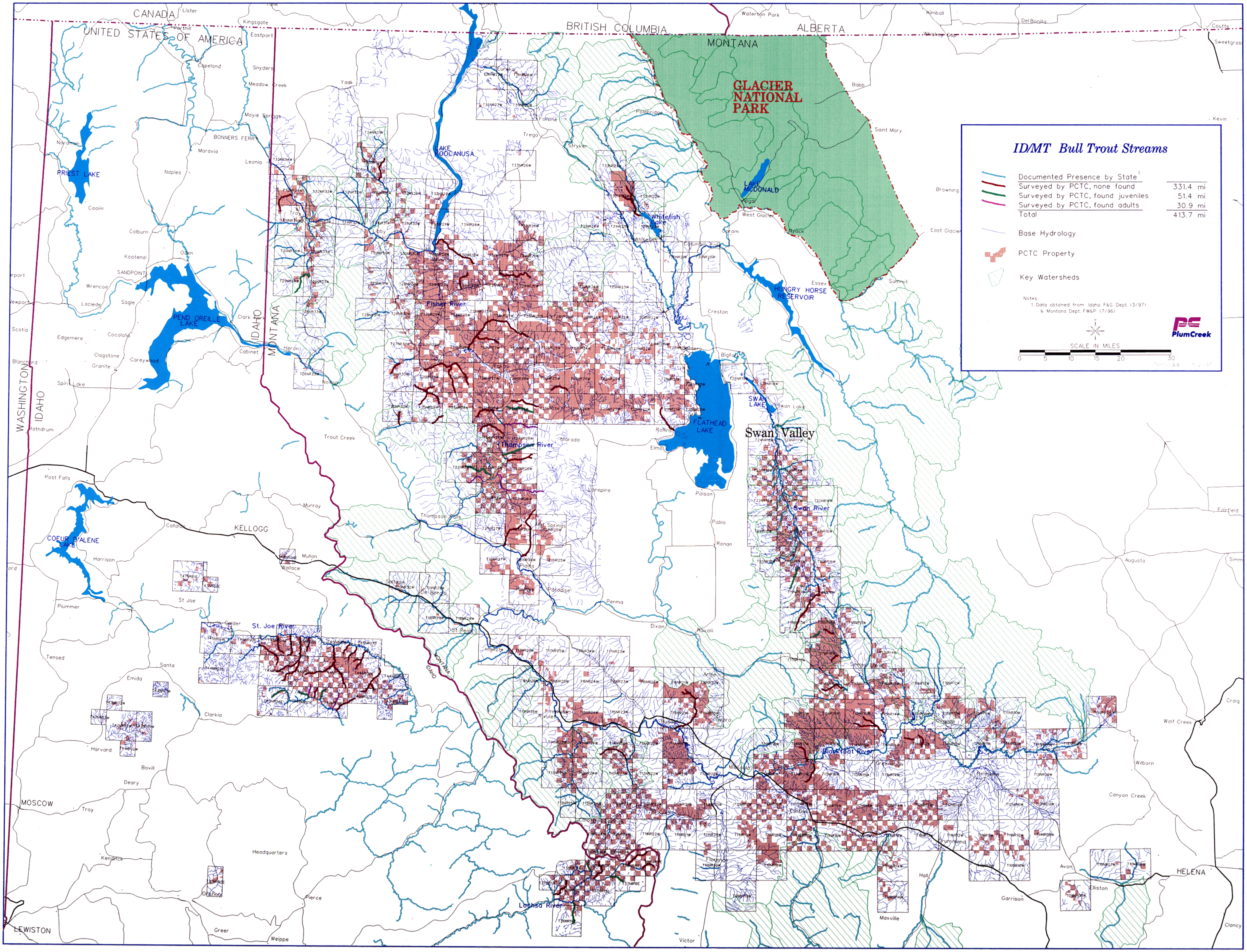
RB/CT = Rainbow Trout/Cutthroat Trout Hybrid,

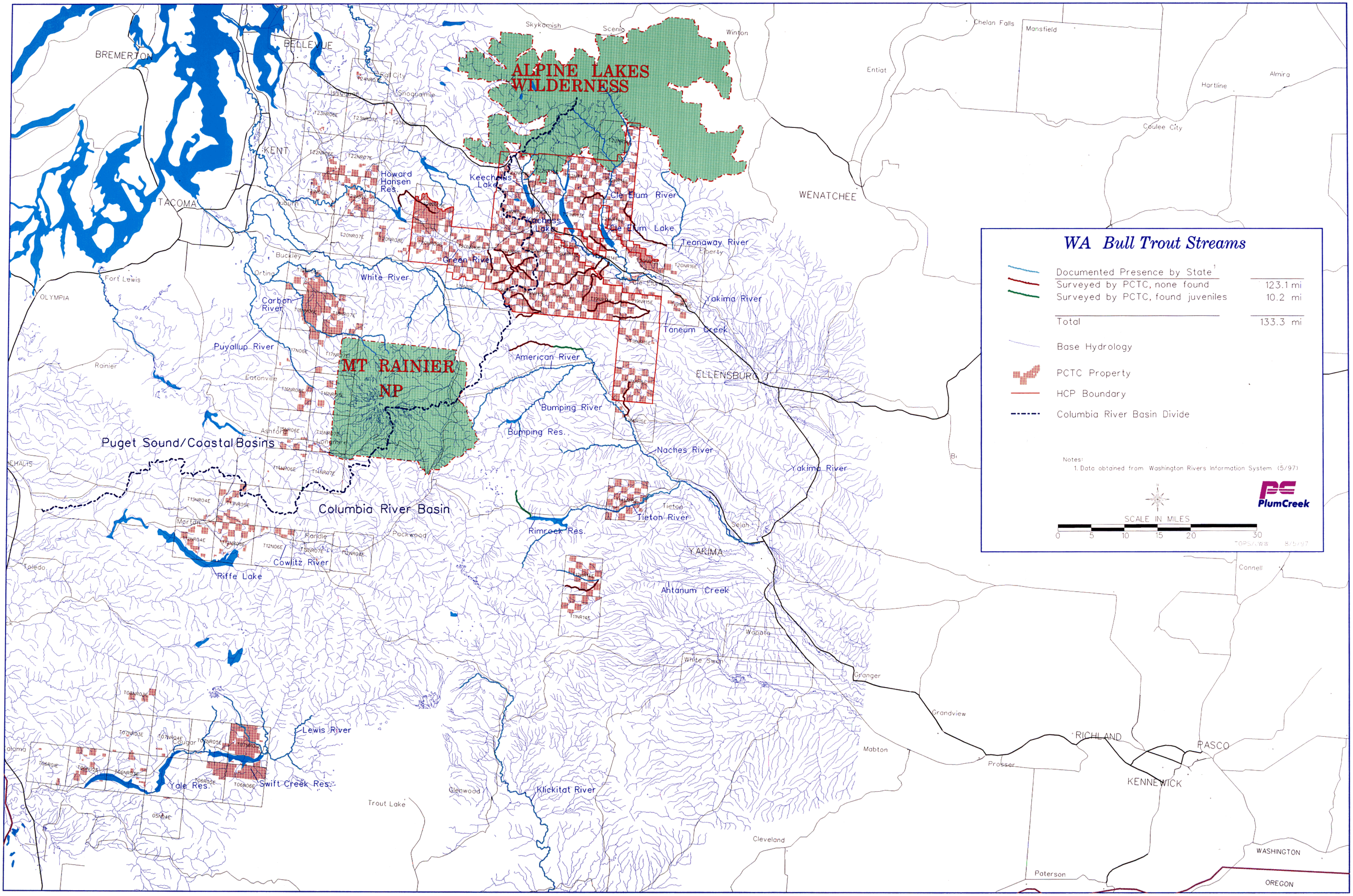
BT/EB = Bull Trout/Brook Trout Hybrid, SF=Squaw Fish,

***Streams where bull trout presence was known prior to surveys sampled for research purposes**

YEAR	STATE	DRAINAGE	TRIBUTARY TO:	KILOMETERS SAMPLED	SPECIES CAPTURED	IF BULL TROUT DETECTED, JUVENILES FOUND?
1993	MT	Lazy Creek	Whitefish Lake	10	EB	
1993	MT	East Fisher River	Fisher River	10	CT, EB, SC	
1993	MT	Owl/Himes Creek	East Fisher River	10	CT, EB	
1993	MT	Shaffer Creek	Pipe Creek (Kootenai River)	10	CT, RB	
1993	MT	Shroder Creek	Thompson River	10	EB, CT, BT	Yes
1993	MT	Dayton Creek	Flathead Lake	10	EB, SU	
1993	MT	Tamarack Creek	Little Bitterroot River	10	RB	
1993	MT	Beaver Creek	Swan River	10	CT, EB, SC	
1993	MT	Bear Creek	Blackfoot River	10	EB, CT, SC, RB, BN	
1993	MT	Finley Creek	Placid Creek (Clearwater River)	10	CT, EB, SC, SU	
1993	MT	Fawn Creek	Clearwater River	10	CT, EB, SC	
1993	MT	East Twin Creek	Blackfoot River	10	CT, EB, RB, BN	
1993	MT	W. Fork Petty Creek	Clark Fork River	10	CT, EB, SC	
1993	ID	Pack Creek	Brushy Fork (Lochsa River)	10	CT, RB	
1993	ID	Upper Brushy Fork	Brushy Fork (Lochsa River)	10	CT, RB	
1993	ID	N. Fork Spruce Creek	Brushy Fork (Lochsa River)	10	CT, RB	
1993	ID	Twin Creek	Brushy Fork (Lochsa River)	10	CT, BT	Yes
1993	ID	Walton Creek	Lochsa River	10	BT, CT	Yes
1993	ID	Parachute Creek	Papoose Creek (Lochsa River)	10	CT, RB	
1993	ID	Red Raven Creek	Fishhook Creek (St. Joe River)	10	CT	
1993	ID	Alpine Creek	Sisters Creek (St. Joe River)	10	CT, SC	
1993	ID	Lick Creek	Fishhook Creek (St. Joe River)	10	CT	
1993	ID	Sisters Creek	St. Joe River	20	CT, SC, WF	
1993	ID	Fishhook Creek	St. Joe River	20	CT, RB, SC	
1993	ID	Boulder Creek	Marble Creek (St. Joe River)	10	CT, RB, SC	
1993	ID	Spotted Louis Creek	Little N. Fork Clearwater River	10	CT, RB	
1993	ID	Lost Lake Creek	Little N. Fork Clearwater River	10	BT, CT	Yes
1993	ID	Montana Creek	Little N. Fork Clearwater River	10	BT, CT	No
1993	ID	Caribou Creek	Priest River	10	CT, EB	
1993	WA	Sema Creek	Granite Creek (Preist River)	10	EB	
1993	WA	LeClerc Creek	Pend Oreille River	10	CT, BN, RB, EB	
1993	WA	W. Branch LeClerc Creek	Pend Oreille River	20	BT, CT, EB, BN, RB	Yes
1993	WA	E. Branch LeClerc Creek	Pend Oreille River	20	BT, CT, EB, BN	Yes
1993	WA	M. Branch LeClerc Creek	Pend Oreille River	10	CT, EB, BN	
1993	WA	W. Fork Teanaway River	Yakima River	10	RB, CT, SC	
1993	WA	Big Creek	Yakima River	20	CT, RB, EB, SC	
1993	WA	S. Fork Taneum Creek	Yakima River	10	CT, RB, EB, SC	
1993	WA	N. Fork Taneum Creek	Yakima River	20	CT, RB, EB, RB/CT, SC	
1993	WA	French Cabin Creek	Cle Elum Lake	10	EB, RB, SC	
1993	WA	Upper Green River	Green River	10	CT, SC, RB, COHO	
1993	WA	Twin Camp Creek	Green River	10	RB, CT, RB/CT, SC	
1993	WA	N. F. Little Naches River	Naches River	10	RB, CT, SC	
1993	WA	M. F. Little Naches River	Naches River	10	RB, CT, SC	
1994	MT	Ruby Creek	Kootenai River	10	CT, SC	
1994	MT	Stanley Creek	Bull Lake	10	BT, EB, SC, CT	Yes
1994	MT	Dunn Creek	Kootenai River	20	RB, CT, RB/CT, SC	
1994	MT	Trail Creek	Fisher River	10	EB, CT, SC	
1994	MT	Murr Creek	Thompson River	10	CT, RB, EB, SC	
1994	MT	Jungle Creek	Thompson River	10	BT, CT, SC	Yes
1994	MT	Deerhorn Creek	Thompson River	10	CT, RB, RB/CT, SC, BT	No
1994	MT	Little Thompson River	Thompson River	20	RB, EB, WF, BT, CT, SC, DA	No
1994	MT	Belmont Creek *	Blackfoot River	10	RB, BT, CT, BN, SC	Yes
1994	MT	Mill Creek	Clark Fork River	10	EB, BN, CT	
1994	MT	Bear Creek	Mill Creek (Clark Fork River)	10	EB, CT	
1994	MT	Lion Creek *	Swan River	10	CT, BT/EB, BT, EB	Yes
1994	MT	Elk Creek *	Swan River	15	EB, BT/EB, BT, SC, CT	Yes

1994	MT	Squeezer Creek *	Swan River	10	EB, BT, CT, BT/EB	Yes
1994	MT	Cold Creek *	Swan River	15	EB, CT, BT, SC	Yes
1994	MT	Goat Creek *	Swan River	10	EB, CT, BT, RB	Yes
1994	MT	Little Wolf Creek	Fisher River	10	EB, CT	
1994	MT	Richards Creek	Fisher River	10	EB, CT	
1994	MT	Elk Creek	Fisher River	10	EB, CT	
1994	MT	McGinnis Creek	Fisher River	20	EB, CT, SC	
1994	MT	Meadow Creek	Thompson River	10	EB	
1994	MT	Lazier Creek	Thompson River	10	RB, CT, RB/CT, SC	
1994	MT	Buffalo Bill Creek	Clark Fork River	10	CT, EB	
1994	MT	Lynch Creek	Clark Fork River	20	BN, EB, CT, SC	
1994	ID	Rock Creek	Lochsa River	10	CT, BT	
1994	ID	Fly Creek *	St. Joe River	5	BT, CT	Yes
1994	ID	Mosquito Creek*	St. Joe River	10	BT, CT, SC	Yes
1994	ID	Medicine Creek*	St. Joe River	10	BT, SC, CT	Yes
1994	ID	E. F. Bluff Creek	St. Joe River	20	SC, CT	Yes
1994	ID	Twin Creek	Little N. Fork Clearwater River	10	CT	
1994	ID	Beaver Creek*	St. Joe River	10	SC, CT, BT	
1994	ID	Simmons Creek*	St. Joe River	10	SC, CT, BT	Yes
1994	ID	Rutledge Creek	Little N. Fork Clearwater River	10	CT, SC, BT	Yes
1994	ID	Allen Creek	St. Joe River	10	CT, SC	Yes
1994	ID	Burton Creek	St. Joe River	10	SC, CT	
1994	ID	Kelly Creek	St. Joe River	10	RB, CT	
1994	ID	Adair Creek	Little N. Fork Clearwater River	10	RB, CT, SC, BT, RB/CT	
1994	ID	Jungle Creek	Little N. Fork Clearwater River	10	CT, SC, BT	Yes
1994	WA	Intake Creek	Green River	10	RB, CT, SC	No
1994	WA	Sawmill Creek	Green River	10	RB, CT, SC	
1994	WA	Domerie Creek	Cle Elum River	10	CT, SC	
1994	WA	Little Creek	Yakima River	20	CT, EB, SC	
1994	WA	Gold Creek *	Keechelus Lake	10	CT, BT, KSA	
1994	WA	Box Canyon Creek *	Kachees Lake	15	BT, CT, RB, SC	Yes
1994	WA	Indian Creek *	Rimrock Lake	10	BT, WF, RB	Yes
1994	WA	Crow Creek *	Little Naches River	20	CSA, RB, SC, DA, BT, CT	Yes
1994	WA	Pioneer Creek	Green River	10	CT, SC	Yes
1994	WA	Tacoma Creek	Green River	10	RB, SC, CT	
1994	WA	Winchester Creek	Pend Orielle River	20	BT/EB, EB, SC, DA, RB, CT, SU, RB/CT	
1994	WA	S. F. Tacoma Creek	Pend Orielle River	10	EB, BN, RB, CT, SC	
1994	WA	Calispell Creek	Pend Orielle River	10	RB, EB	
1994	WA	CeeCeeAh Creek	Pend Orielle River	10	BN, EB, SC, CT	
1995	MT	Bear Creek	Thompson River	10	EB, CT	
1995	MT	Chippy Creek	Thompson River	10	EB, BT, CT, BT/EB	
1995	MT	Big Rock Creek	Thompson River	10	EB, BT, CT, WF	Yes
1995	MT	Kraft Creek	Glacier Creek (Swan River)	10	EB, BT, CT	No
1995	MT	Marshall Creek	Clearwater River	10	EB, BT, CT, DA, RB	Yes
1995	MT	Barnum Creek	Pleasant Valley Fisher River	10	EB, CT, RB, SC	Yes
1995	MT	Pleasant Valley Fisher River	Fisher River	20	EB, SU, CY, DA, RB, SC, SF, SH, WF	
1995	MT	E. F. Chamberlain Creek	Blackfoot River	10	CT, RB, SC, RB/CT	
1995	MT	W. F. Chamberlain Creek	Blackfoot River	10	RB, SC	
1995	MT	Lyons Gulch Creek	Vermillion River	10	CT	
1995	MT	Willow Creek	Vermillion River	10	EB, CT	
1995	MT	Blanchard Creek	Clearwater River	10	CT, RB, SC, WF, RB/CT, EB	
1995	MT	N. F. Blanchard Creek	Clearwater River	10	EB, CT, RB	
1995	WA	Rock Creek	Little Naches River	10	RB, CT, SC, DA	
1995	WA	Cottonwood Creek	Colville River	10	RB, EB, SC, DA	
1995	WA	N.F. Green River	Green River	15	RB, CT, SC, RB/CT	
1995	WA	M.F. Ahtanum Creek	Ahtanum Creek (Yakima River)	10	CT, SC, COHO	
1995	ID	Flemming Creek	St. Joe River	10	RB, CT, SC	
1995	ID	Periwinkle Creek	Nugget Creek (St. Joe River)	10	CT, SC	
1995	ID	Prospector Creek	St. Joe River	10	CT, SC	
1995	ID	Nugget Creek	St. Joe River	10	RB, CT, SC	
1995	ID	Fall Creek	Deep Creek (Pack River)	15	RB, EB, CT, SC, DA	
1997	MT	Twin Creek	Thompson River	10	BT	
1997	WA	S.F. Ahtanum Creek	Ahtanum Creek (Yakima River)	20	BT, CT, RB, DA, SH, SC	Yes
1997	WA	M.F. Ahtanum Creek*	Ahtanum Creek (Yakima River)	10	BT, CT	No
1997	WA	Foundation Creek	N.F. Ahtanum Creek (Yakima Rive	10	CT, SC	No
1997	WA	Nasty Creek	N.F. Ahtanum Creek (Yakima Rive	10	CT, SC	
1997	WA	Oak Creek	Tieton River	10	RB, EB, CT	
1997	WA	Bear Creek	Little Naches River	10	CT	
1997	WA	Rocky Run Creek	Lake Keechelus (Yakima River)	10	CT	


ID/MT Bull Trout Streams
Documented Presence by State[1]
Surveyed by PCTC, none found 331.4 mi
Surveyed by PCTC, found juveniles 51.4 mi
Surveyed by PCTC, found adults 30.9 mi
Total 413.7 mi
Base Hydrology
PCTC Property
Key Watersheds
Notes:
1. Data obtained from Idaho F&G Dept. (3/97) & Montana Dept. FW&P (7/96)
SCALE IN MILES
0 5 10 15 20 30
PlumCreek
CANADA
UNITED STATES OF AMERICA
BRITISH COLUMBIA
ALBERTA
MONTANA
IDAHO
WASHINGTON
GLACIER NATIONAL PARK
LAKE KOOCANUSA
PRIEST LAKE
PEND OREILLE LAKE
COEUR D'ALENE LAKE
FLATHEAD LAKE
HUNGRY HORSE RESERVOIR
SWAN LAKE
LAKE MCDONALD
Whitefish Lake
Swan Valley
Fisher River
Thompson River
Swan River
St. Joe River
Blackfoot River
Lochsa River
KELLOGG
MOSCOW
LEWISTON
HELENA



WA Bull Trout Streams
Documented Presence by State[1]
Surveyed by PCTC, none found 123.1 mi
Surveyed by PCTC, found juveniles 10.2 mi
Total 133.3 mi
Base Hydrology
PCTC Property
HCP Boundary
Columbia River Basin Divide
Notes:
1. Data obtained from Washington Rivers Information System (5/97)
SCALE IN MILES
0 5 10 15 20 30
PlumCreek
ALPINE LAKES WILDERNESS
MT RAINIER NP
Puget Sound/Coastal Basins
Columbia River Basin
BREMERTON
BELLEVUE
KENT
TACOMA
OLYMPIA
Fort Lewis
Skykomish
Scenic
Winton
Chelan Falls
Mansfield
Entiat
Hartline
Almira
Coulee City
WENATCHEE
Howard Hansen Res.
Keechelus Lake
Kachess Lake
Cle Elum River
Cle Elum Lake
Teanaway River
Liberty
Yakima River
Taneum Creek
ELLENSBURG
Green River
White River
Carbon River
Puyallup River
Buckley
Orting
Auburn
Snoqualmie
Fall City
Rainier
Eatonville
Ashford
Longmire
American River
Bumping River
Bumping Res.
Naches River
Tieton River
Rimrock Res.
Selah
YAKIMA
Ahtanum Creek
Morton
Randle
Packwood
Cowlitz River
Riffe Lake
Toledo
CHEHALIS
Connell
Wapato
White Swan
Granger
Grandview
RICHLAND
PASCO
KENNEWICK
Prosser
Mabton
Lewis River
Cougar
Swift Creek Res.
Yale Res.
Trout Lake
Glenwood
Klickitat River
Cleveland
Paterson
WASHINGTON
OREGON